Stock Assessments in Support of U.S. Fisheries

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Objectives

Describe the context for stock assessments in fisheries management

Describe the assessment process and associated components of that process

Complete exercise where you interpret scientific advice from assessments to make management decisions

Presentation Outline

- Mandate for Stock Assessments
- Supporting Fishery Management Plans
- Stock Assessment Process
- Harvest Control Rules

Mandate for Stock Assessments

Magnuson-Stevens Act (MSA)

- The MSA does not explicitly mandate assessments (unlike MMPA)

However,

- MSA language *implies* that assessments are necessary

Mandate for Stock Assessments

MSA: National Standards 1, 2, 3

NS1

- "…prevent overfishing while achieving…optimum yield"

NS2

- "…best scientific information available"

NS3

- *"…an individual stock …shall be managed as a unit throughout its range"*

Mandate for Stock Assessments

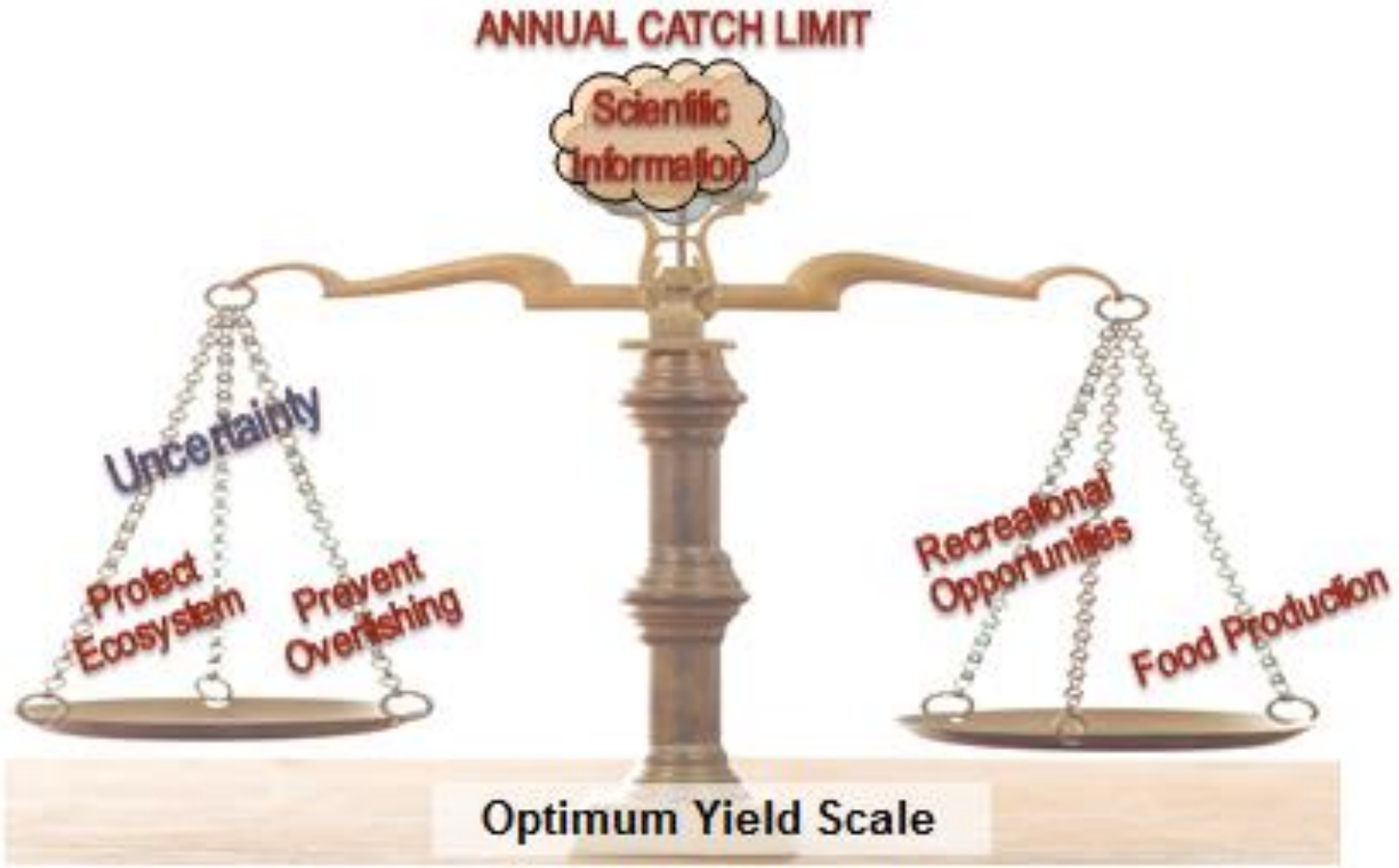
MSA: Fishery Management Plans

"…annual catch limits…such that overfishing does not occur…including measures to ensure accountability."

"…objective and measurable criteria for identifying when the fishery … is overfished…related to reproductive potential of stock"

…ACLs may not exceed Scientific and Statistical Committee's fishing level recommendation…based on best scientific information available"

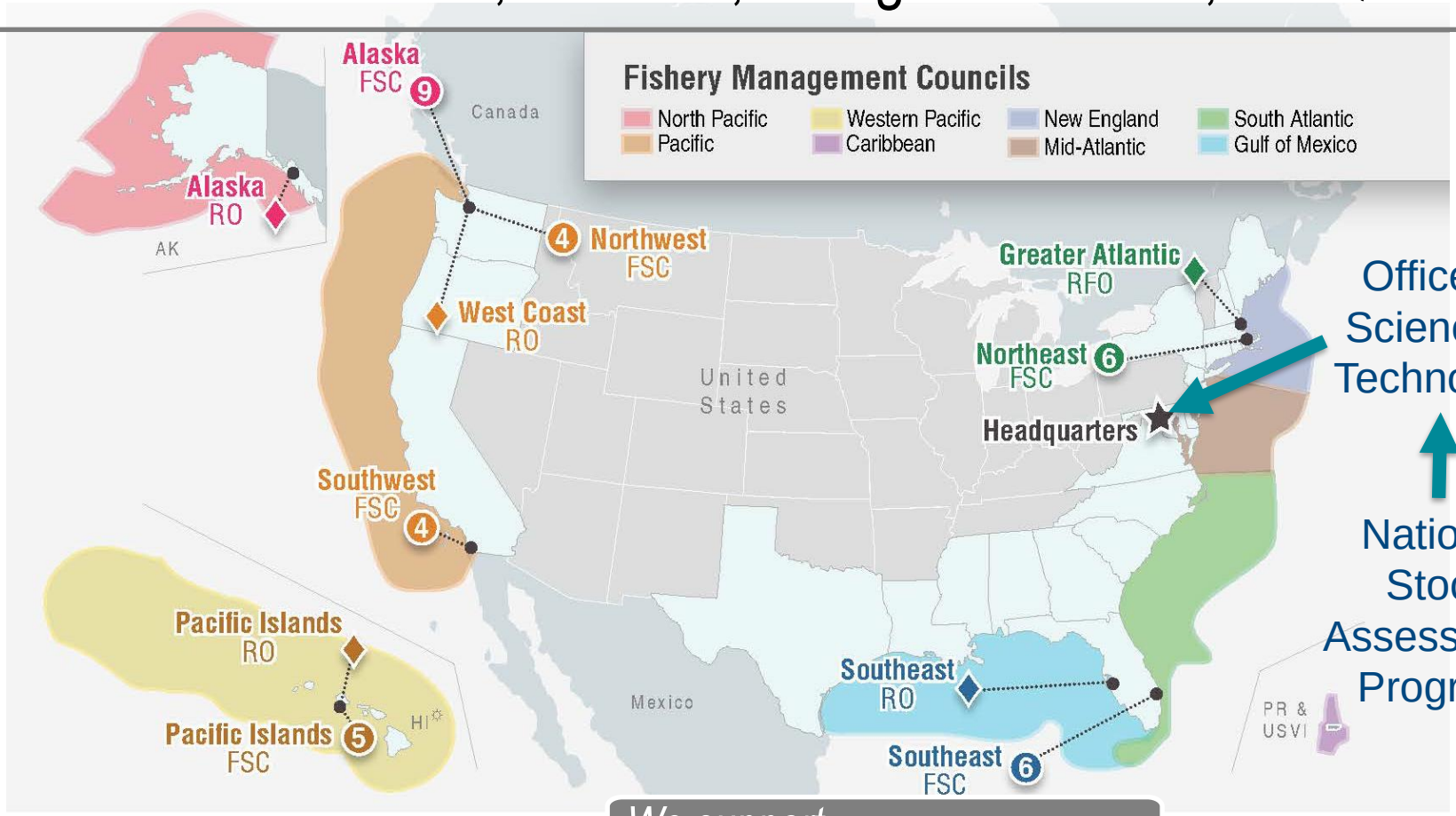
Mandate for Stock Assessments



NOAA Fisheries Science to Support Fisheries Management

We have…

- **6** Science Centers; **20+** labs; **5** Regional Offices; & **HQ**



Office of Science & Technology

National Stock Assessment Program

We support…

- **8** regional Fishery Mgmt. Councils

NOAA Fisheries Science to Support Fisheries Management

- In addition to the 8 U.S. Councils…
- At least 16 management & advisory organizations supported

Fishery Management & Advisory Organizations

▲ Advisory (not management) organization.

Organization		Supported by NOAA Fisheries Science Center(s)	Managed Ecosystem	Managed Stocks
ADFG	Alaska Dept. of Fish & Game	AK	Gulf of Alaska & Bering Sea - Sub-Arctic	Numerous Alaska coast stocks
CCAMLR	Commission for the Conservation of Antarctic Living Marine Resources	SW	Antarctic	Toothfishes, Icefish, & Krill
CCSBT	Commission for the Conservation of Southern Bluefin Tuna	AK	Southern Hemisphere Oceans	Southern bluefin tuna
IATTC	Inter-American Tropical Tuna Commission	SW, PI	Eastern Pacific Ocean - Sub-Arctic to Tropical	Tunas, Billfish, Sharks
IPHC	Int'l Pacific Halibut Commission	AK	Pacific Coast - Temperate to Sub-Arctic	Pacific halibut
ISCTTS▲	Int'l Scientific Committee for Tuna & Tuna-Like Species in the Northern Pacific Ocean	PI	Northern Pacific Ocean	Tunas, Billfish, Sharks
NPFC	Northern Pacific FC	AK	Northern Pacific Ocean - Sub-Arctic to Sub-Tropical	Numerous groundfish, Pelagics, Invertebrates
NPFMC	Northern Pacific FMC	AK	Gulf of Alaska & Bering Sea - Sub-Arctic	Groundfish, Salmon, Crab, Scallops
PFMC	Pacific FMC	AK, NW, SW	California Current	Salmon, Groundfish, pelagics, HMS
PSC▲	Pacific Salmon Commission	AK, NW	Pacific Coast, Bays, Rivers, & Estuaries	Pacific salmon stocks
PSMFC▲	Pacific States Marine FC	AK, NW, SW	Pacific Coast, Bays, Rivers, & Estuaries	Numerous Pacific coast stocks
PWS	Pacific Whiting Treaty	NW	California Current - Temperate	Pacific whiting (Pacific hake)
SPRFMO	Southern Pacific Regional FMO	AK, PI	Southern Pacific Ocean	Jack mackerel, Chub mackerel, Squids
WCPFC	Western & Central Pacific FC	PI	Western & Central Pacific Ocean	Tunas, Billfish, Sharks
WPFMC	Western Pacific FMC	PI	Insular Pacific Hawaii - Tropical	Bottomfish, Reef fishes, HMS, Invertebrates
ASMFC	Atlantic States Marine FC	NE, SE	U.S. East Coast, Bays, & Estuaries	Coastal groundfish, Pelagics, Invertebrates, Anadromous fishes
CFMC	Caribbean FMC	SE	Caribbean Sea - Tropical	Reef fishes, Invertebrates, Migratory pelagics
GOMFMC	Gulf of Mexico FMC	SE	Gulf of Mexico - Tropical/Subtropical	Reef fishes, Invertebrates, Migratory pelagics
GSMFC	Gulf States Marine FC	SE	Coastal Gulf of Mexico - Tropical/Subtropical	Gulf menhaden, Blue crab, Many commercial/rec. stocks
ICCAT	Int'l Commission for the Conservation of Atlantic Tunas	SE	Atlantic Ocean - Sub-Arctic to Tropical	Tunas, Billfish, Sharks
MAFMC	Mid-Atlantic FMC	NE	Northeast U.S. Continental Shelf (Mid-Atlantic Bight)	Groundfish, Clams & quahogs, Pelagic fishes & squids
NAFO	Northwest Atlantic FO	NE	Northwest Atlantic Ocean	Groundfish, Squid, Shrimp
NASCO	North Atlantic Salmon Conservation Org.	NE	Northeast U.S. Continental Shelf (Georges Bank) - Temperate Climate	Georges Bank groundfish stocks shared by U.S. & Canada
NEFMC	New England FMC	NE	Northeast U.S. Continental Shelf (New England)	New England groundfish, Sea scallops, Red crab, Atlantic herring, Atlantic salmon
SAFMC	South Atlantic FMC	SE	Southeast U.S. Continental Shelf	Reef fishes, Invertebrates, Migratory pelagics
TMGC	Transboundary Mgmt. Guidance Committee	NE	Northeast U.S. Continental Shelf (Georges Bank) - Temperate Climate	Georges Bank groundfish stocks shared by U.S. & Cananda

Science Centers

AK Alaska
NE Northeast
NW Northwest
SE Southeast
SW Southwest
PI Pacific Islands

Geography

AK - Alaska | CA - California | CT - Connecticut
FL - Florida | HI - Hawaii | LA - Louisiana
MA - Massachusetts | ME - Maine | MS - Mississippi
NC - North Carolina | NJ - New Jersey | NY - New York
OR - Oregon | PR - Puerto Rico | RI - Rhode Island
TX - Texas | U.S. - United States
USVI - U.S. Virgin Islands | WA - Washington

Shorthand / Acronyms

Dept. Department
FC Fisheries Commission
FMC Fisheries Management Council
FMO Fisheries Management Organization
FO Fisheries Organization
HMS Highly Migratory Species
Int'l International
Isl. Islands
Mgmt. Management
Org. Organization
Rec. Recreational (fisheries)

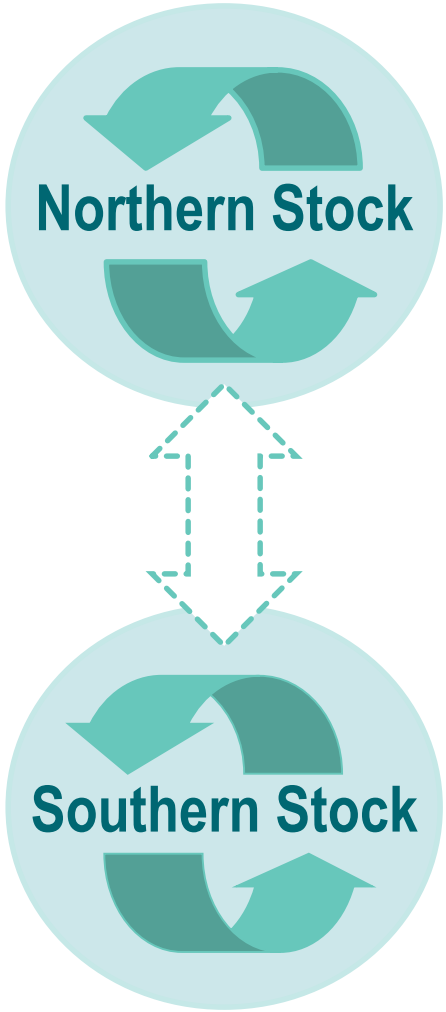
What is a “stock”?

A biological stock

- Group of individuals of the same species
- Inhabit the same geographic region
- Mix and interbreed when mature

A management stock

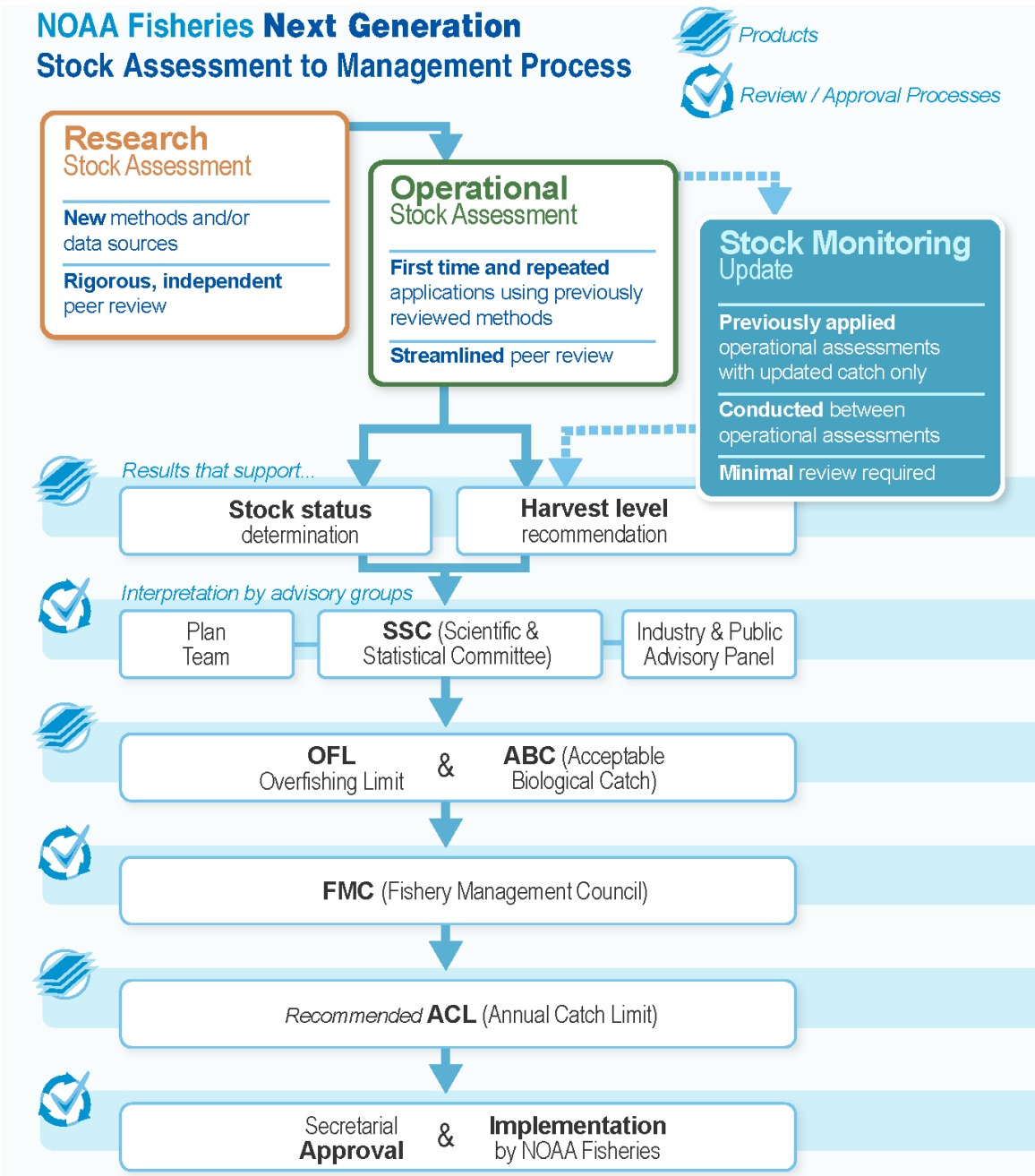
- Often a biological stock
- Sometimes not:
  - Multispecies complex
  - Geopolitical boundaries



What is a stock assessment?

Purpose	Measure stock status relative to defined limits
	Project harvest levels that optimize yield, prevent overfishing, and rebuild depleted stocks
Process	Collecting, analyzing, and reporting demographic information to determine the effects of fishing (and other drivers)

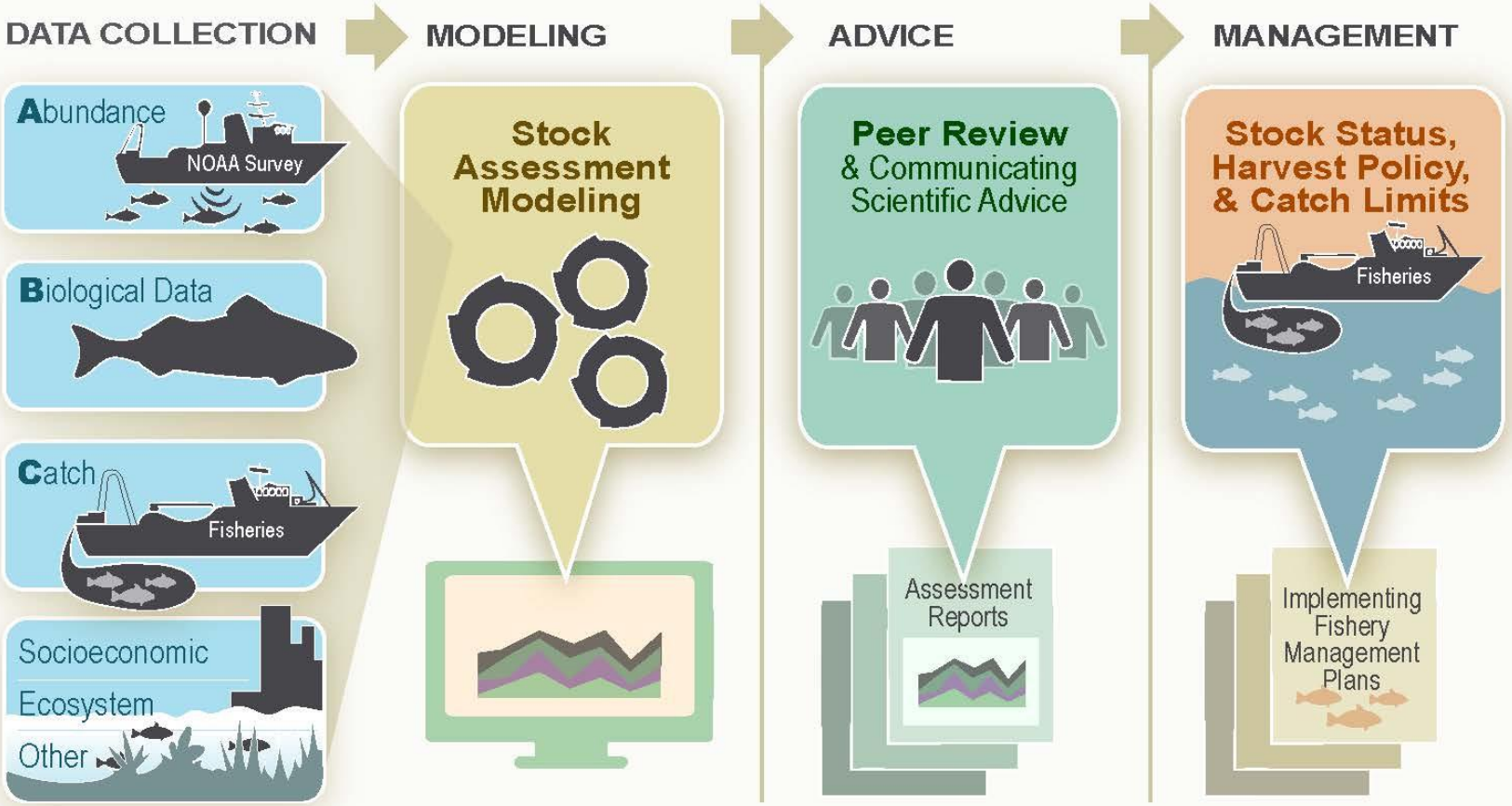
NOAA Fisheries **Next Generation** Stock Assessment to Management Process



NOAA Fisheries Stock Assessment Process

The Science Behind Sustainable Fisheries Management

Healthy Fish Stocks
= Sustainable Jobs, Fisheries, and Food



Stock Assessment Process

Data Collection & Processing: **CATCH**

Catch

- Commercial landings
- Recreational landings
- Commercial/recreational discards & releases (% survival)
- Research removals

Catch Data Sources

- Fishery Information Networks (state, federal, commission)
- Fishery statistics
- Observer programs
- Marine Recreational Information Program

Stock Assessment Process

Data Collection & Processing: **ABUNDANCE**

Fishery-independent:
scientific surveys

- Statistical sampling design (minimize bias)
- Full stock range (even low density areas)
- Standardized gear and practices

Fishery-dependent:
commercial / recreational

- Catch per unit of effort (CPUE)
- May not reflect abundance — market dynamics and changing practices

Stock Assessment Process

Data Collection & Processing: **SURVEY METHODS**

Extractive

- Trawl, longline, hook and line, pot, seine, gill net, dredge, etc.

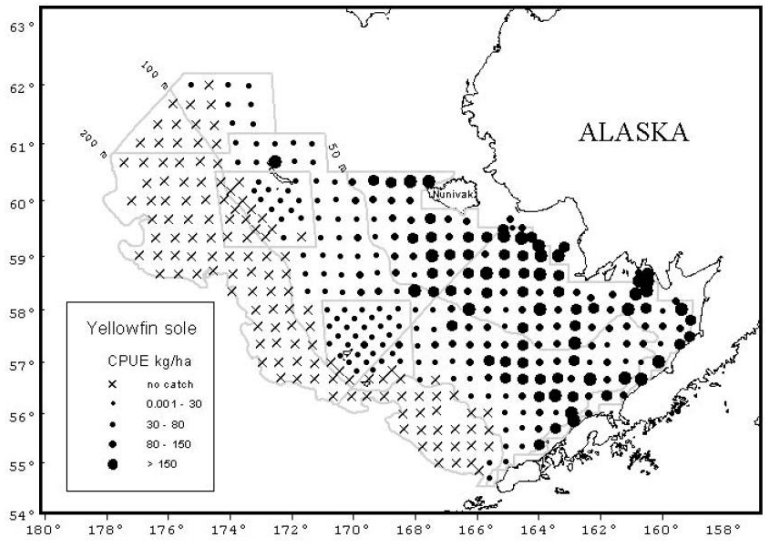
Non-extractive

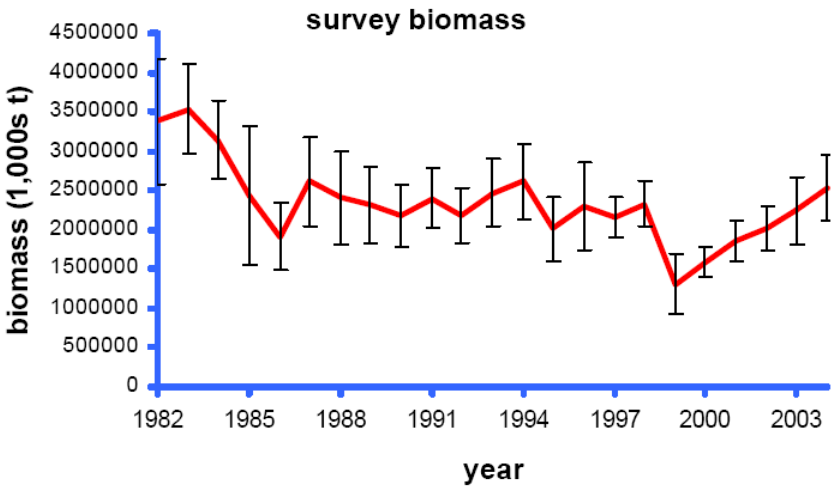
- Acoustic, picture/video, diving, aerial, tag and release, etc.

Extractive Survey Example

Bering Sea Bottom Trawl

- Fish counted/measured at 100s of sites
- Avg. biomass estimated w/error for each year
- Multiple stocks sampled simultaneously
- Similar surveys in other regions (NE, Gulf of Mexico, Pacific & Gulf of AK)

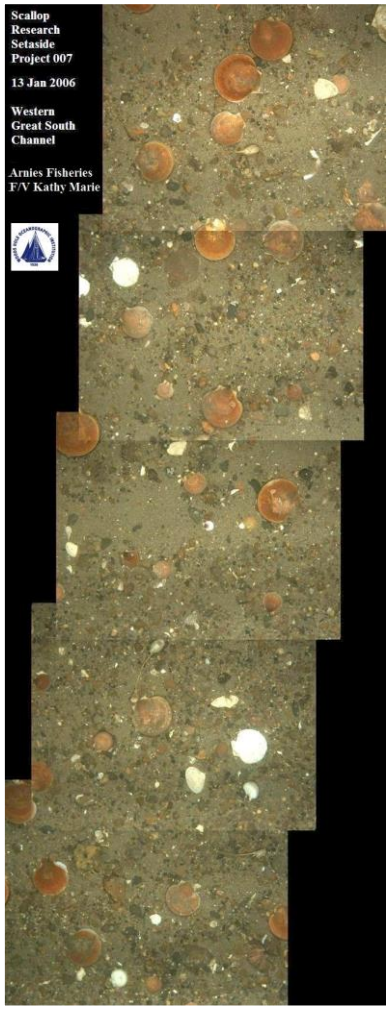




Non-extractive Survey Example

Northeast Scallop Survey

- Advanced sampling technology
- Towed camera system
- Automated recognition software for abundance estimates
- Non-lethal, hence no samples for biological measurements
- Similar techniques being tested and applied across regions



Stock Assessment Process

Data Collection & Processing: **BIOLOGY**

Biology

- Age, Length, Weight, Maturity, Fecundity, Natural Mortality
- Diverse characteristics across stocks

Biology Data Sources

- Scientific surveys
- Observer programs
- Port sampling
- Research & tagging studies

Which of these is NOT a Critical Assessment Data Component?

- ❑ Catch
- ❑ Environmental data
- ❑ Abundance survey
- ❑ Fish Biology

Which of these is NOT a Critical Assessment Data Component?

- ☐ Catch
- ☑ Environmental data
- ☐ Abundance survey
- ☐ Fish Biology

Stock assessment process

Stock Assessment Modeling: **Population dynamics**

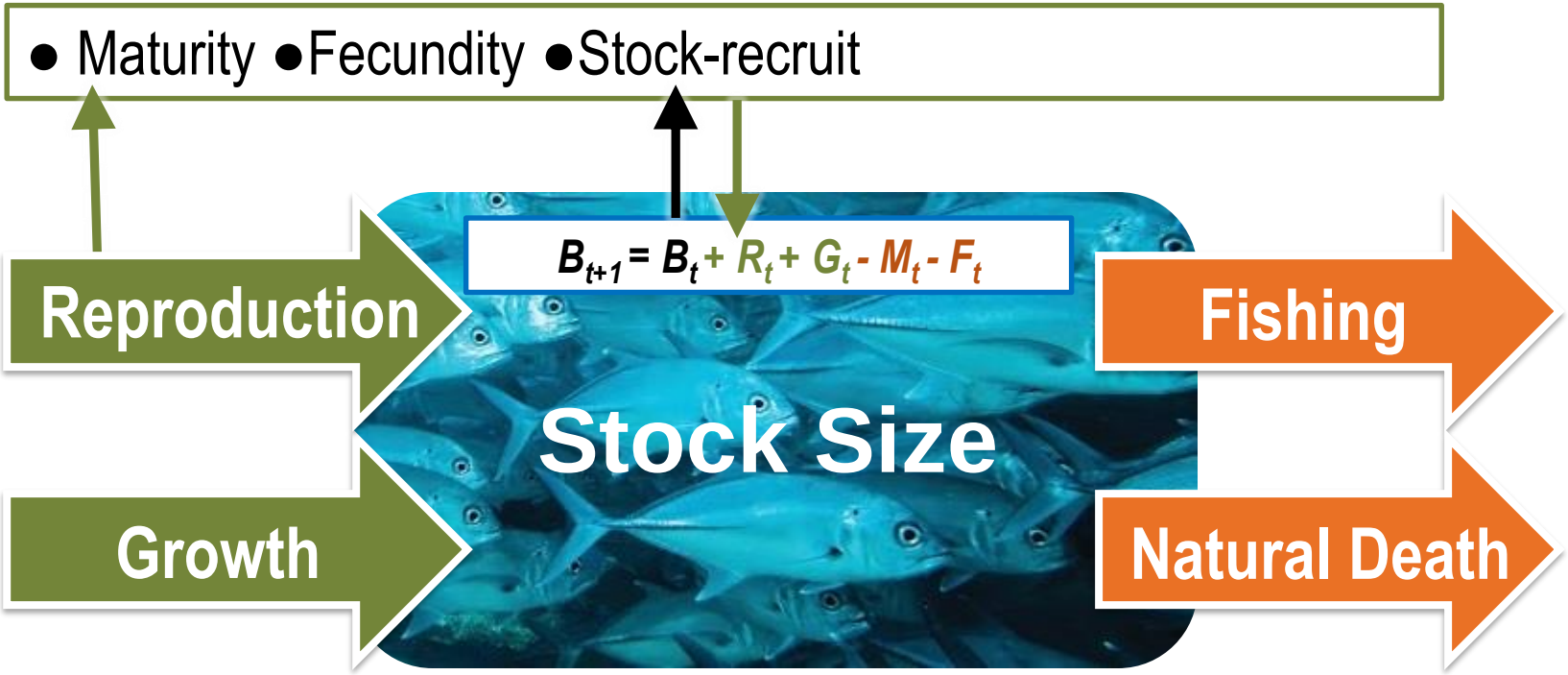
Stock assessment process

Stock Assessment Modeling: **Population dynamics**

- Mathematical models

Stock assessment process

Stock Assessment Modeling: **Population dynamics**



- Mathematical models

Stock assessment process

Stock Assessment Modeling: **Population dynamics**

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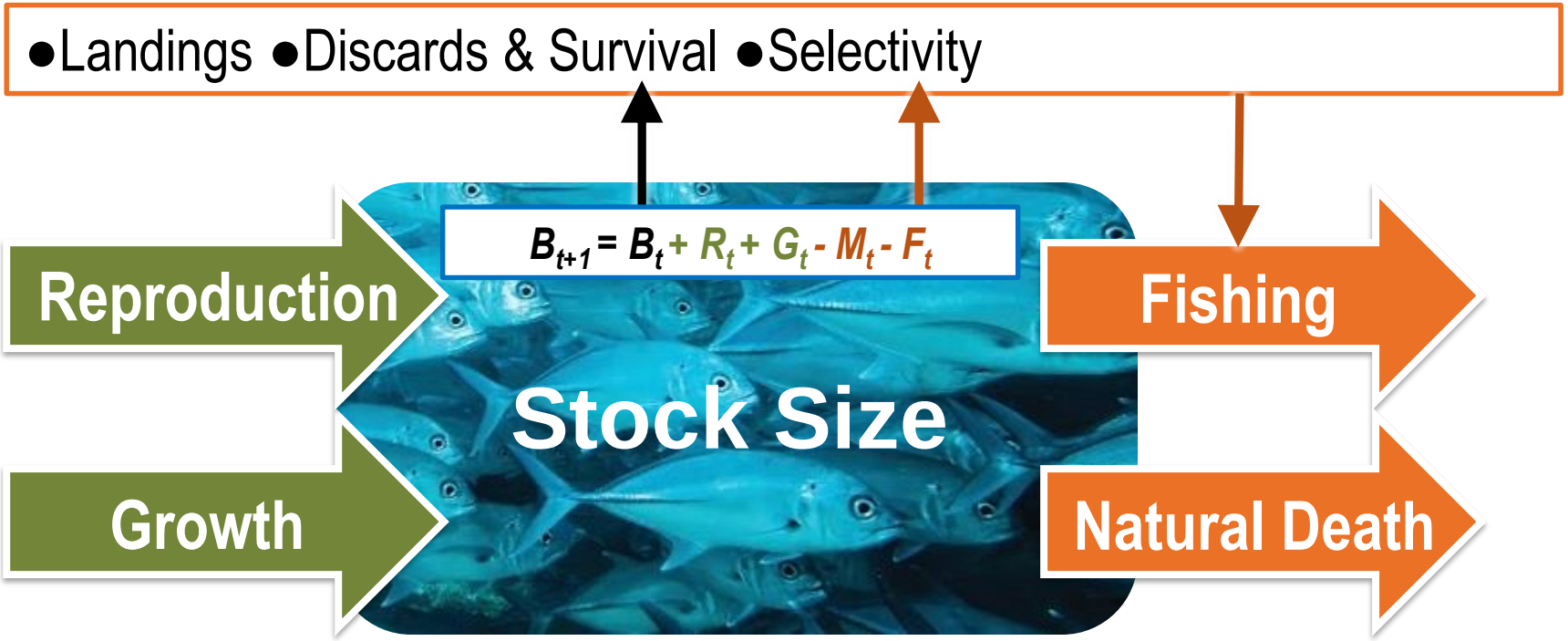
Stock assessment process

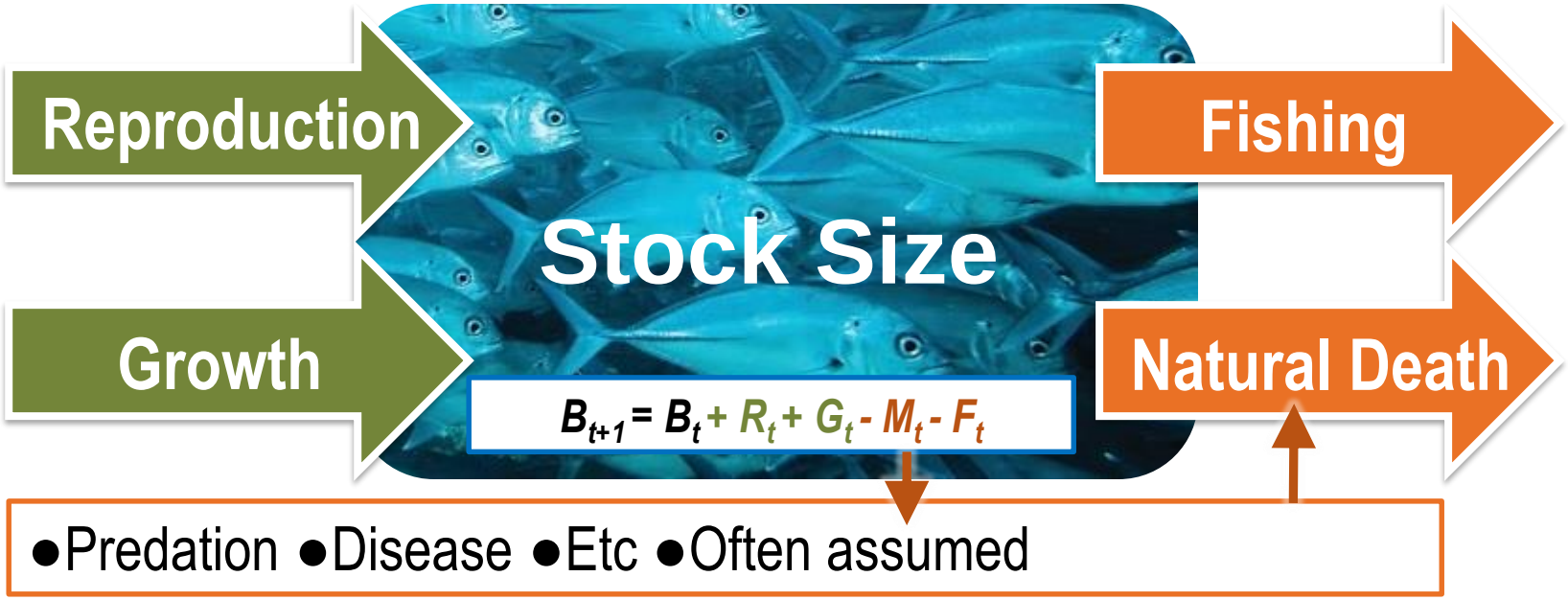
Stock Assessment Modeling: **Population dynamics**



- Mathematical models

Stock assessment process

Stock Assessment Modeling: **Population dynamics**



- Mathematical models

Stock assessment process

Stock Assessment Modeling: **Statistics**

- **Estimation:** observations compared with model predictions
  - Identify dynamics that best represent patterns in data

Stock assessment process

Stock Assessment Modeling: **Statistics**

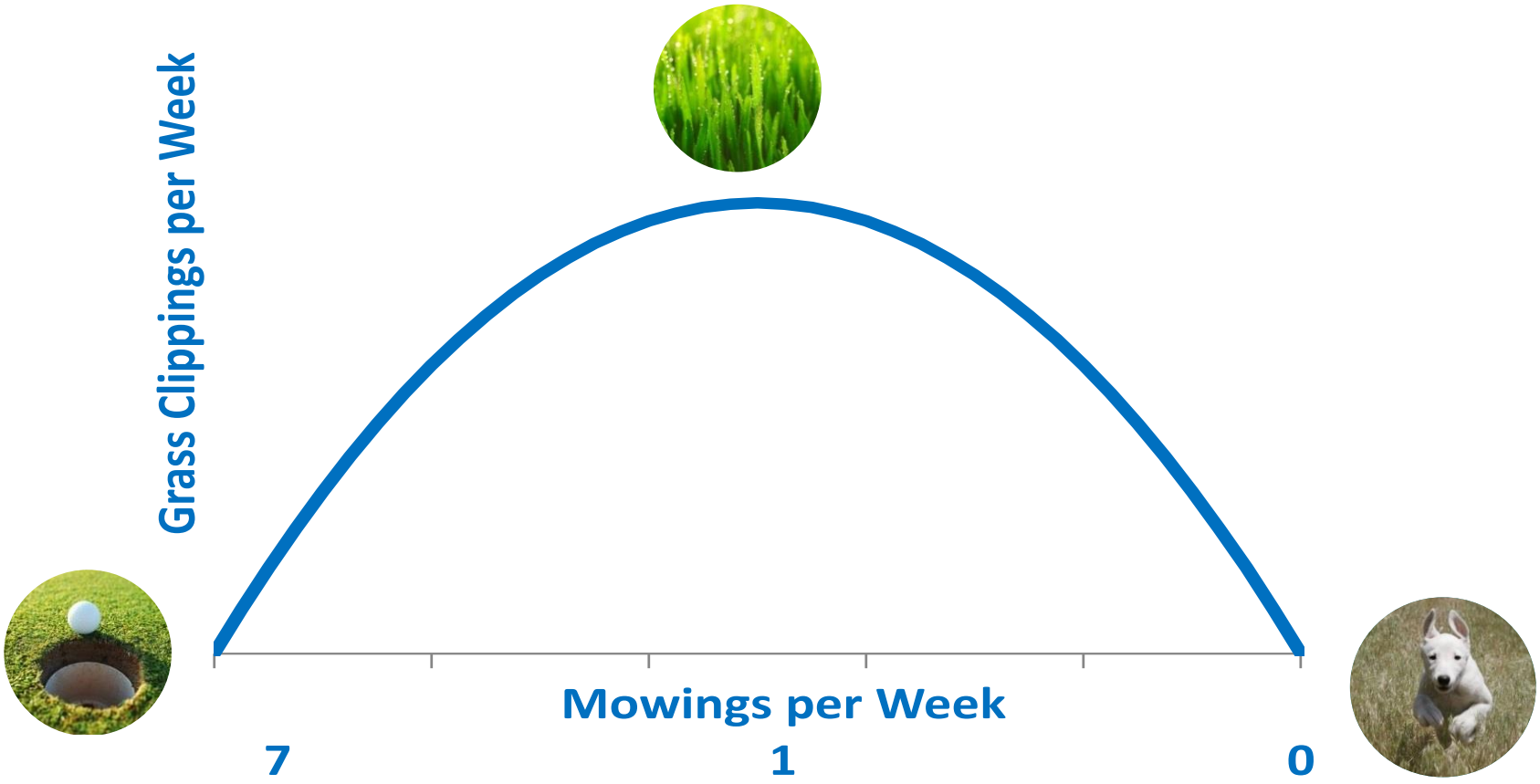
- **Forecasts:** use model(s) & knowledge about the future to project dynamics and identify sustainable practices

"It's hard to make predictions, especially about the future."

Yogi Berra (c. 1925–2015)

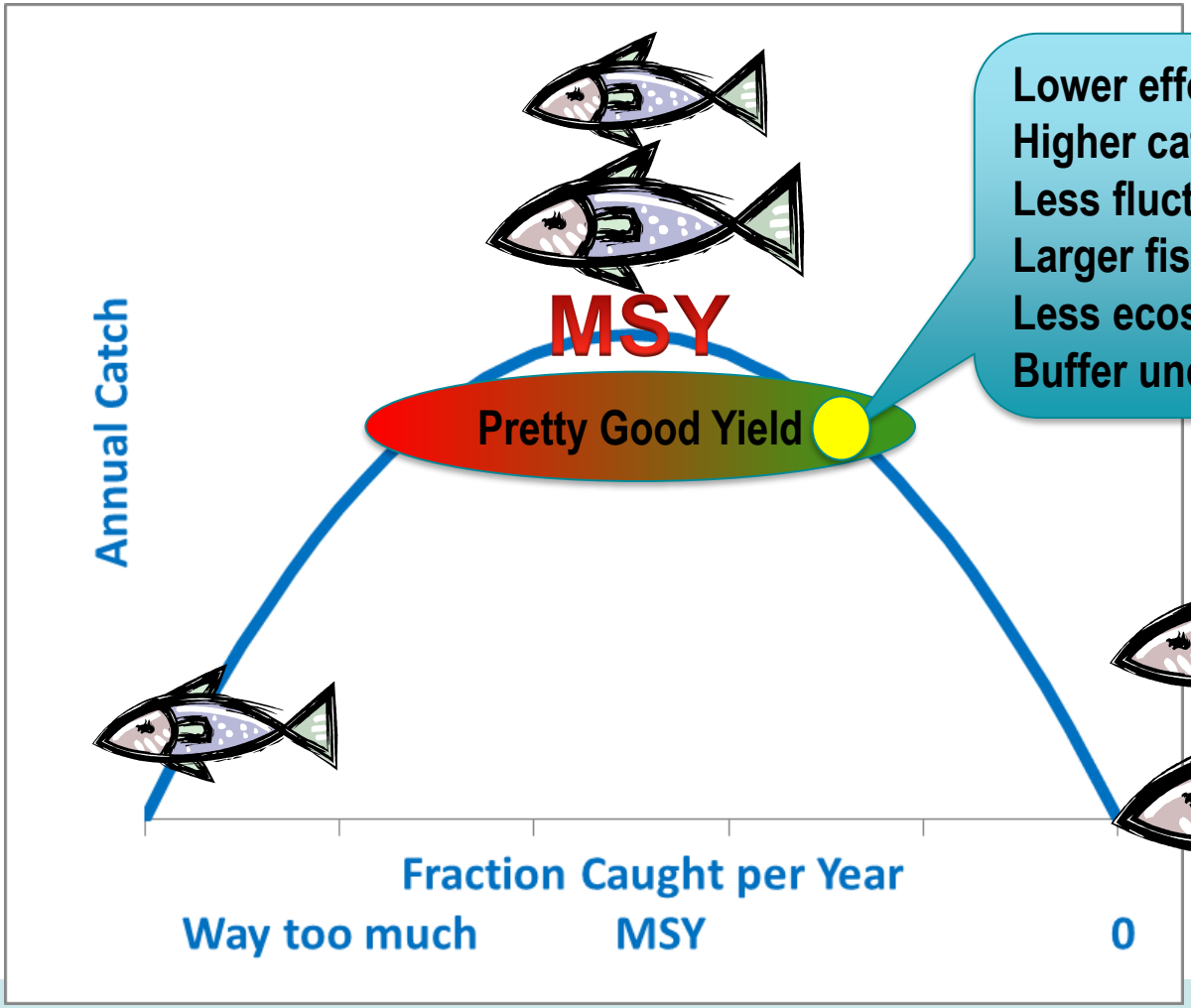
Stock assessment process

Stock Assessment Modeling: **What is sustainable?**



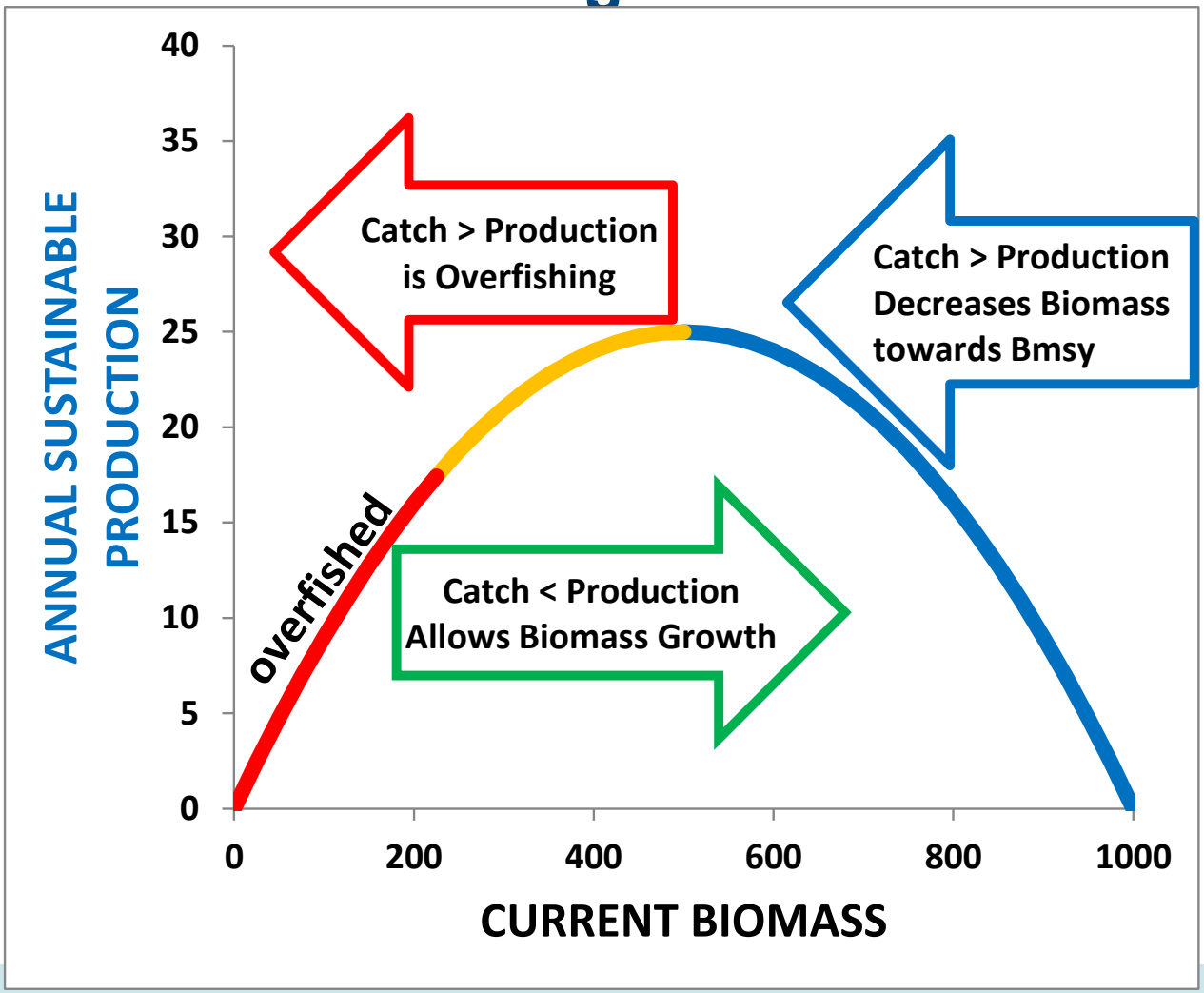
Stock Assessment Process

Stock Assessment Modeling: What is sustainable?



Stock Assessment Process

Stock Assessment Modeling: What is sustainable?

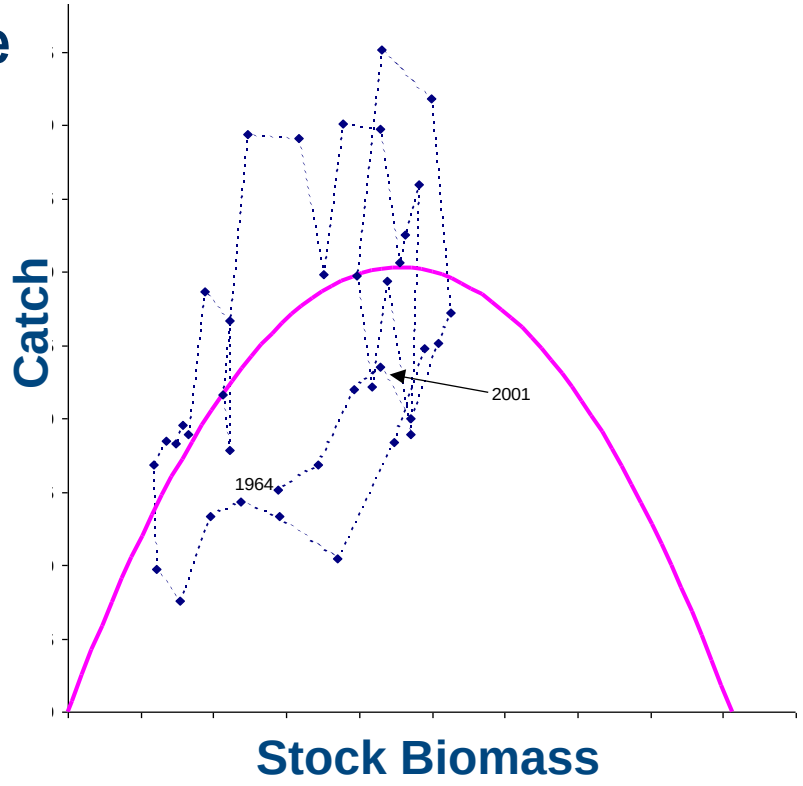


Stock Assessment Process

Stock Assessment Modeling: What is sustainable?

Surplus production reality

- Biology dictates sustainable fishing rate
  - Short life & fast growth = higher rates
- Uncertainty in calculating curve
  - Natural variation
  - Sampling error
  - Contrast – observations across range of biomass
  - Observed biomass is usually relative (age data helps w/scale)



Stock Assessment Process

Stock Assessment Modeling: Types of models

Statistical catch-at-age/length (SCAA)	• Detailed data (catch, abundance, & biology including tagging) – most complete dynamics • Project forward from start year
Virtual Population Analysis (VPA)	• Backward projecting from end year • Often less flexible/more assumptions that SCAA
Biomass dynamics (production models)	• Not age-specific (catch and abundance index only) • MSY can be calculated directly
Index-based	• Time series analysis of fishery or survey trends • Rumble strip approach between more complete types
Data-limited	• Data-limited approaches • Life-history (biology) based

Stock assessment process

Stock Assessment Modeling: Which method to use??

- Models are a simplification of the real world that aim to capture the essence of how a piece of the world works

"All models are wrong, but some are useful."

"It is vain to do with more what can be done with fewer."

George E. P. Box (c. 1919–2013)

William of Ockham (c. 1287–1347)

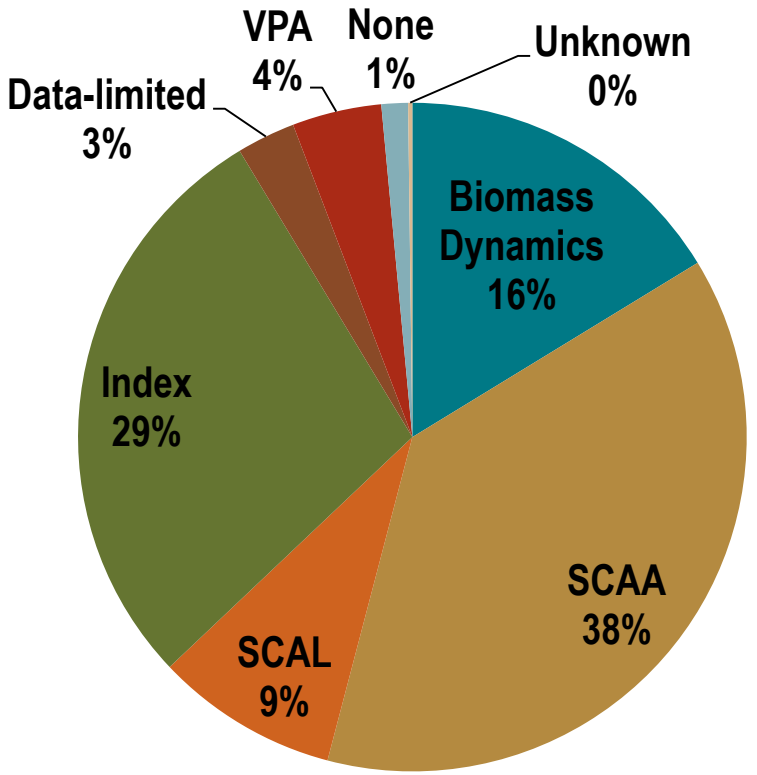
Stock Assessment Process

Stock Assessment Modeling: Which method to use??

Model choice:

- Data available
- What's appropriate for a given stock
- Multiple models may be appropriate

*NMFS Stock Assessment Approaches 2005-2014



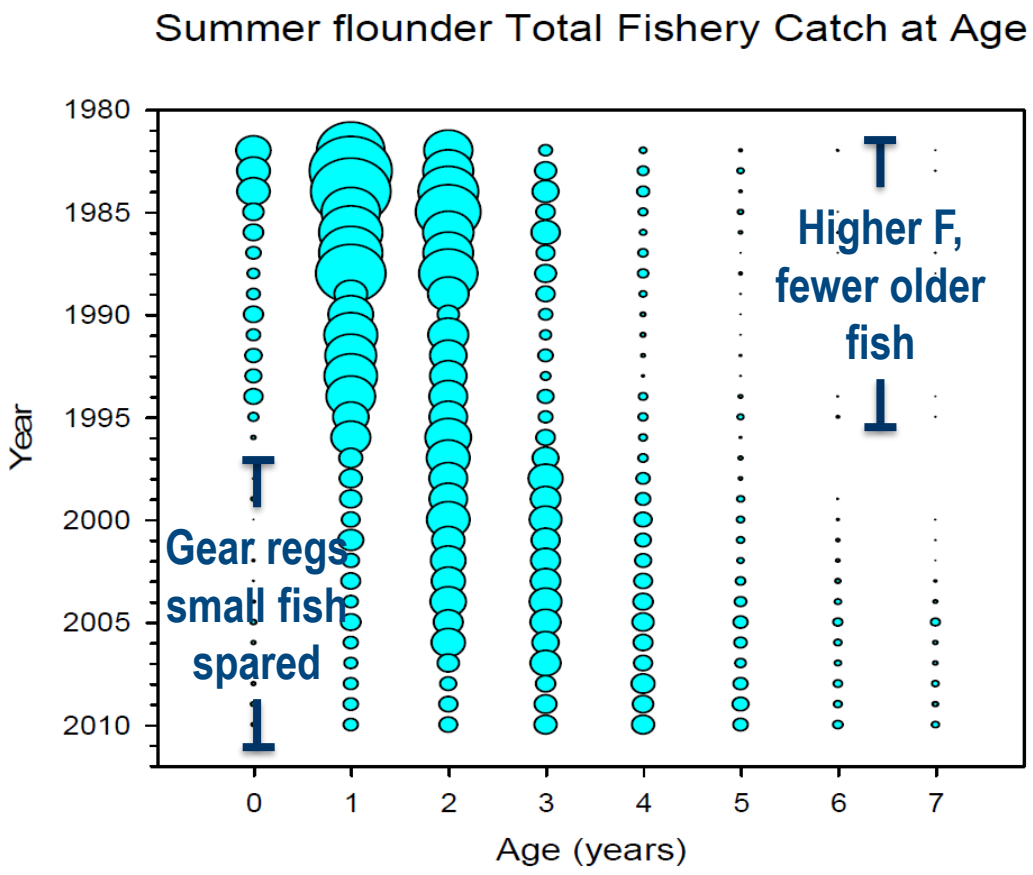
*Data not inclusive of all NMFS assessments

Stock Assessment Process

Stock Assessment Modeling: Which method to use??

Age data provide important details on fishing effects

- Encouraged for valuable or important stocks
- Fishing effects
  - Higher total mortality
  - Age & size structure
  - Generation time
  - Growth rates
  - Other attributes…

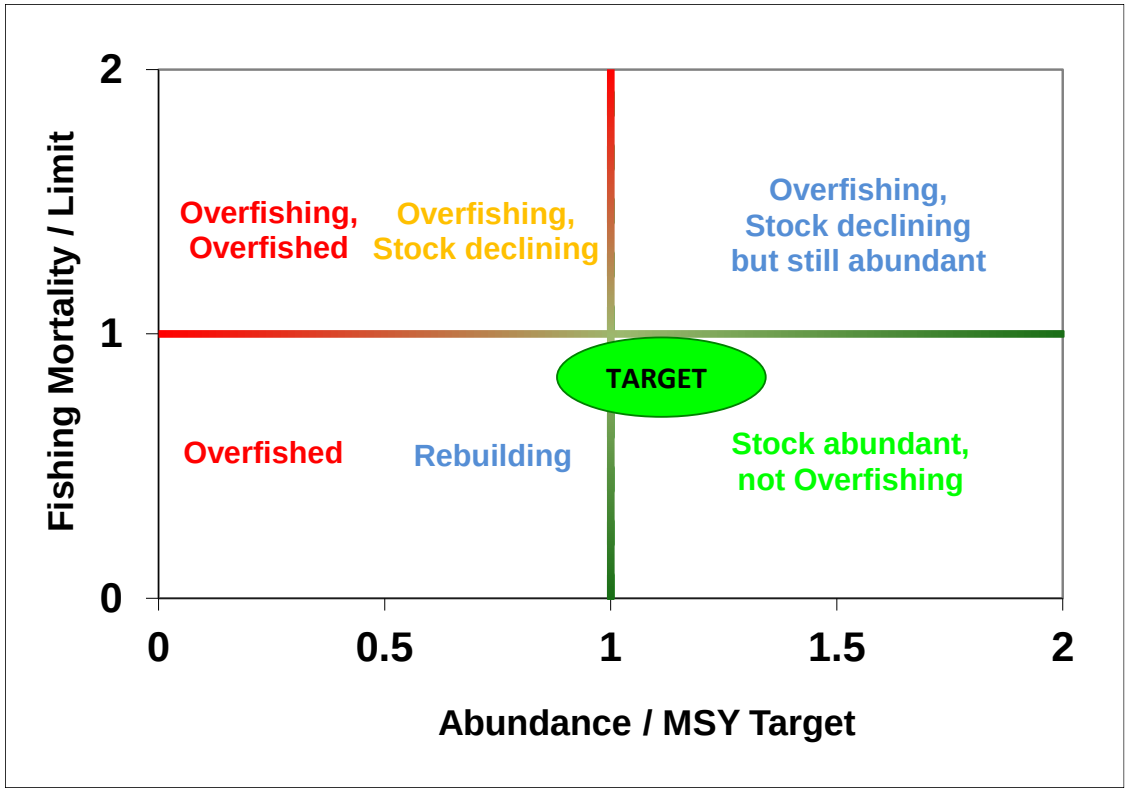


Stock Assessment Process

Developing & Communicating Recommendations

Stock status

- Current fishing rate and biomass levels relative to mgmt. reference points

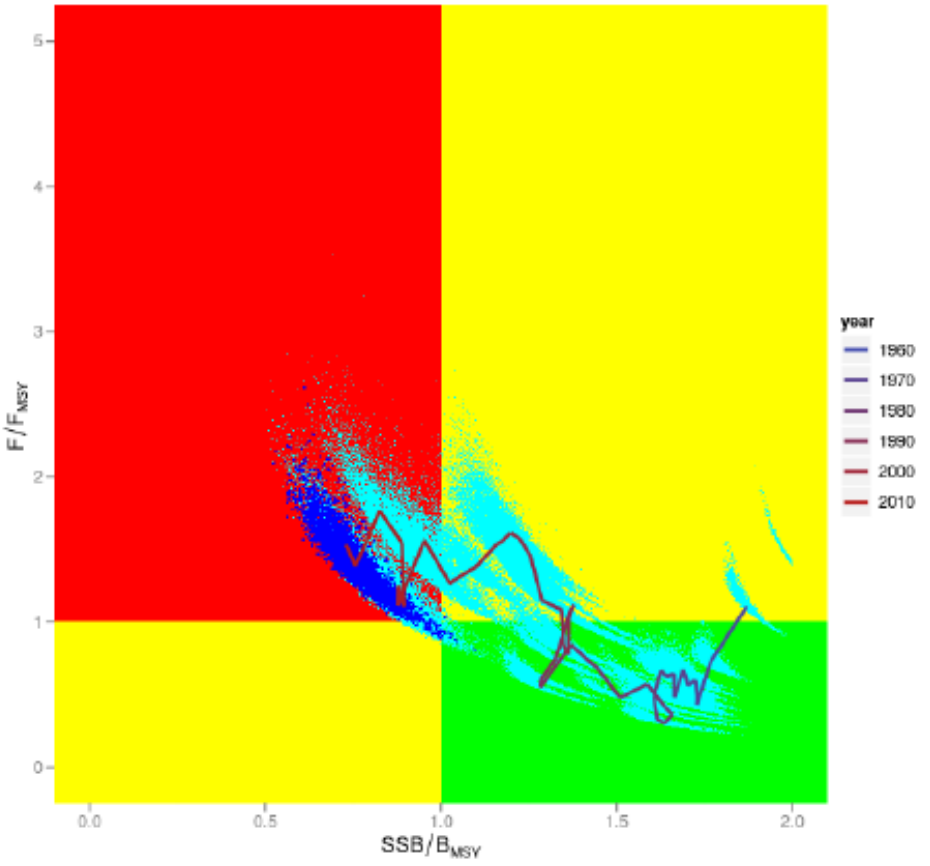


Stock Assessment Process

Developing & Communicating Recommendations

Stock status

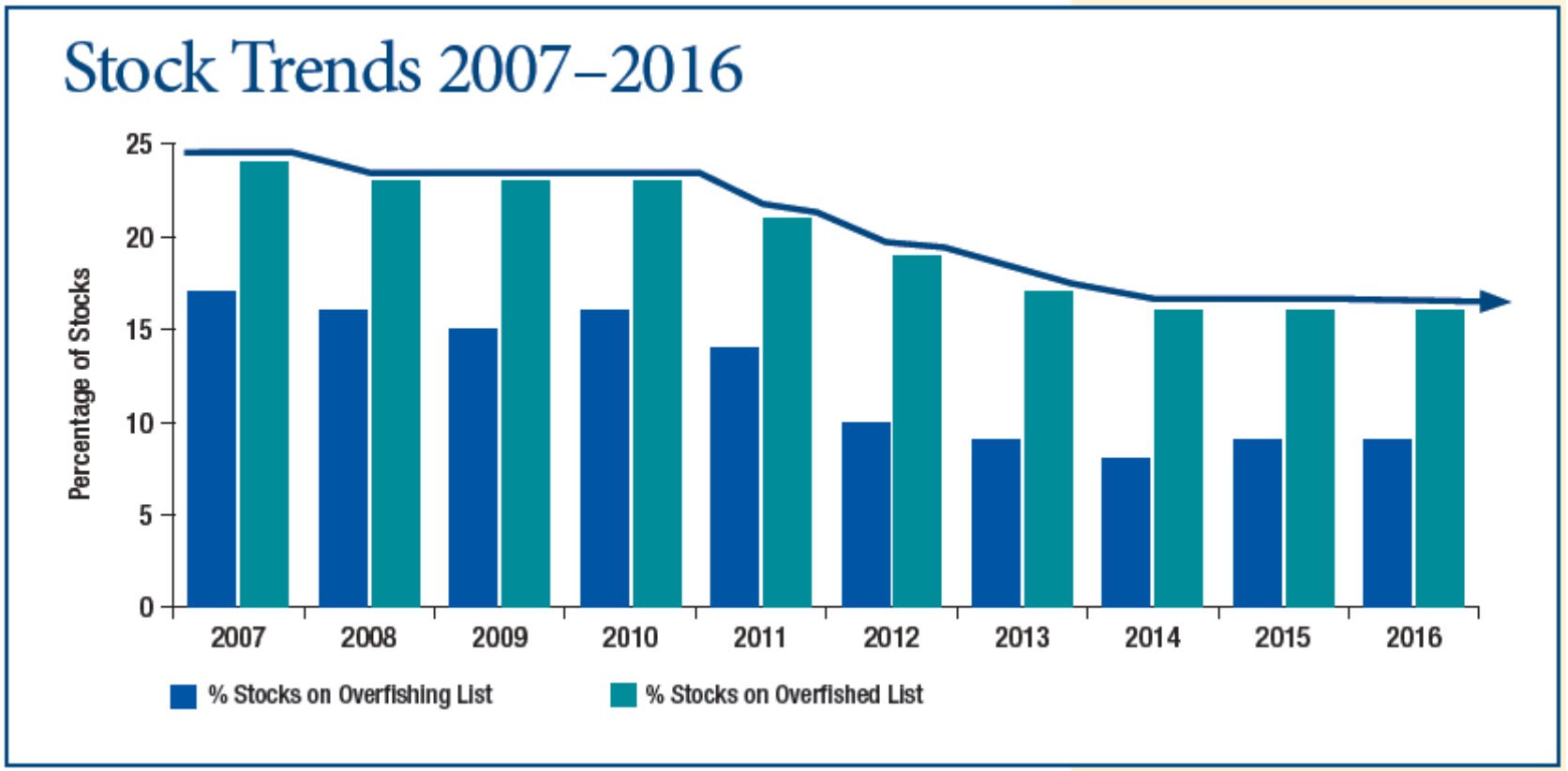
- Current fishing rate and biomass levels relative to mgmt. reference points
- Example time series



Stock Assessment Process

Developing & Communicating Recommendations

Stock status – national summary



Stock Assessment Process

Developing & Communicating Recommendations

Proactive short-term advice: catch levels

- In accordance with harvest policy
  - No more than specified (<=50%) chance of overfishing
  - Rebuild overfished stocks
  - Maximize benefits while protecting marine ecosystems

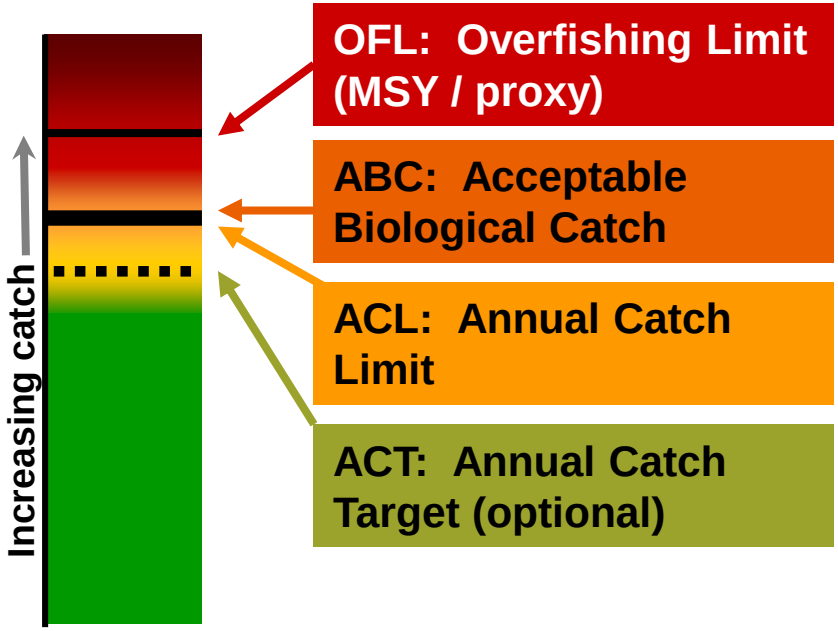
- Control rule: formula that calculates future catch level from forecasted biomass

Stock Assessment Process

Developing & Communicating Recommendations

Proactive short-term advice: catch levels

- NS1 Guidelines (2009)
- ABC accounts for scientific uncertainty
- If ABC = OFL, no uncertainty
- ABC = ACL is OK (science mgmt. handoff)
- ACL triggers accountability
- ACT accounts for mgmt. uncertainty

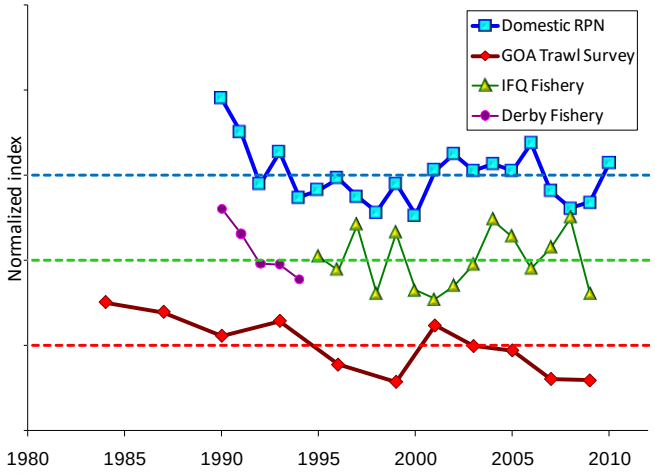


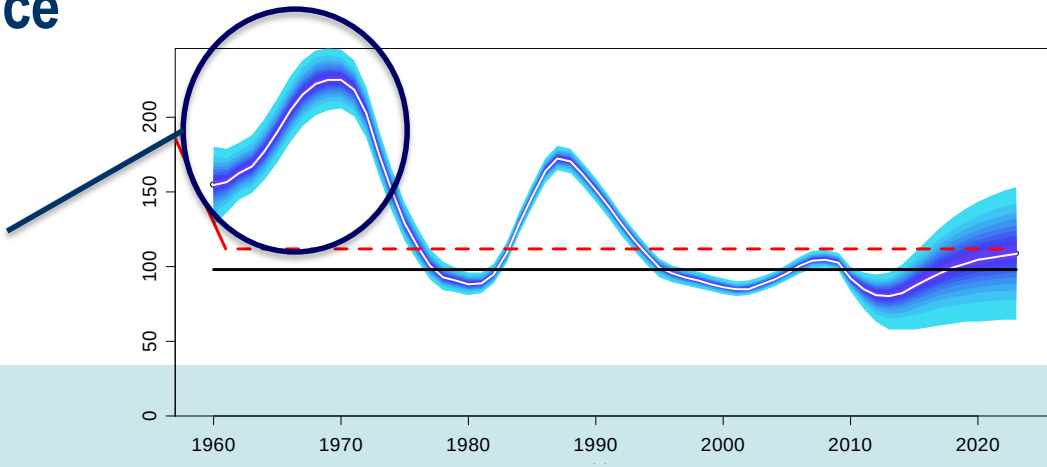
Stock Assessment Process

Developing & Communicating Recommendations

Proactive short-term advice: uncertainty

- Uncertainty is the reality
  - Models are simplifications & data are incomplete
  - Uncertainty ≠ bad science
- Example: Sablefish
  - Multiple indices of abundance
  - Catch monitoring predates abundance tracking
  - Higher uncertainty in years w/out surveys



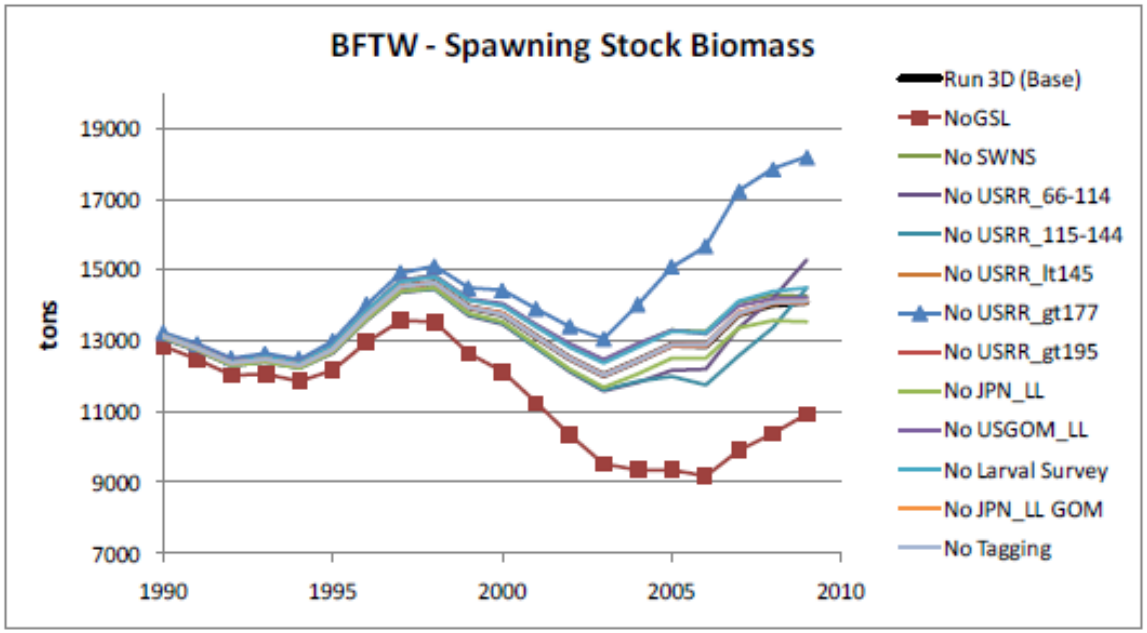


Stock Assessment Process

Developing & Communicating Recommendations

Proactive short-term advice: uncertainty

- Methods for characterizing uncertainty:
  - Statistical error
  - Sensitivity analysis →
  - Multiple models
  - Retrospective analysis
  - Management strategy evaluation

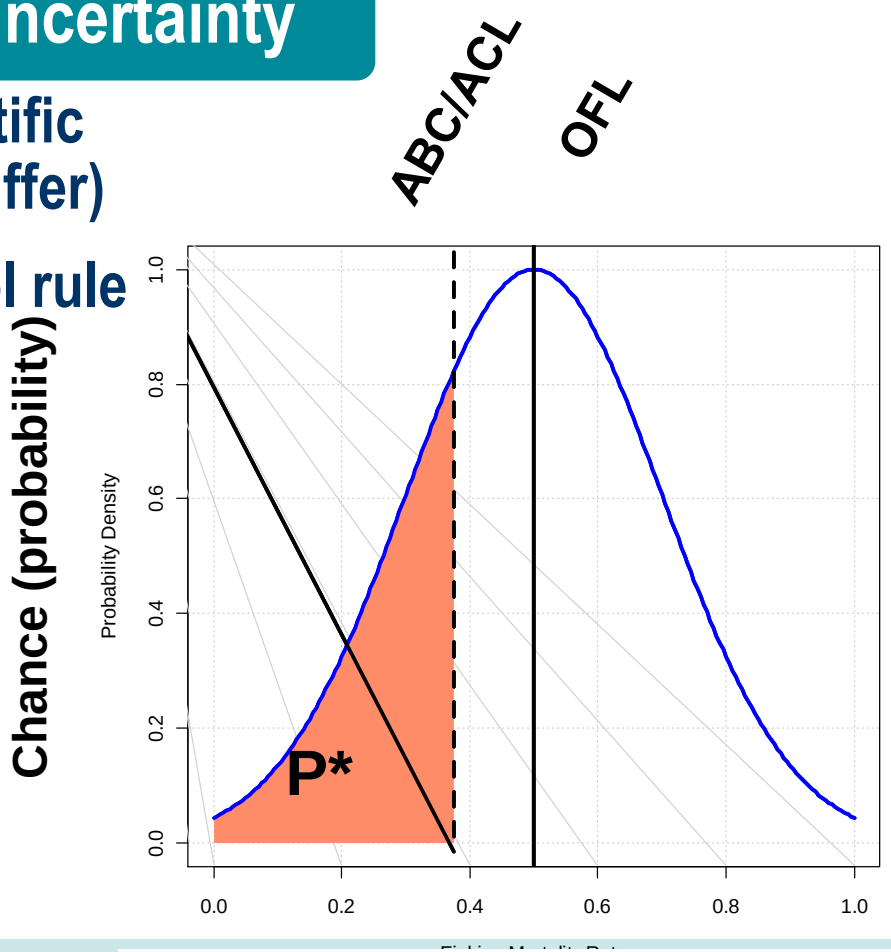


Stock Assessment Process

Developing & Communicating Recommendations

Proactive short-term advice: uncertainty

- SSCs expected to address scientific uncertainty with ABCs (safety buffer)
- One approach: P* harvest control rule
  - Fig: uncertainty around OFL
  - P* = chance that true OFL < ABC (overfishing)
  - Using P* = 40% identifies an ABC that has 40% chance of exceeding true OFL



P* harvest control rule analogy

How much coffee will council members drink this year?

- Council Training as sample of total council consumption
- Calculate: average # cups per person per day
- Purchase = avg. * # of council members * # council meeting days
- Risk & uncertainty
  - Estimate is too low: not enough coffee for everyone
  - Estimate is too high: coffee disposal fee could bankrupt councils

P* harvest control rule analogy

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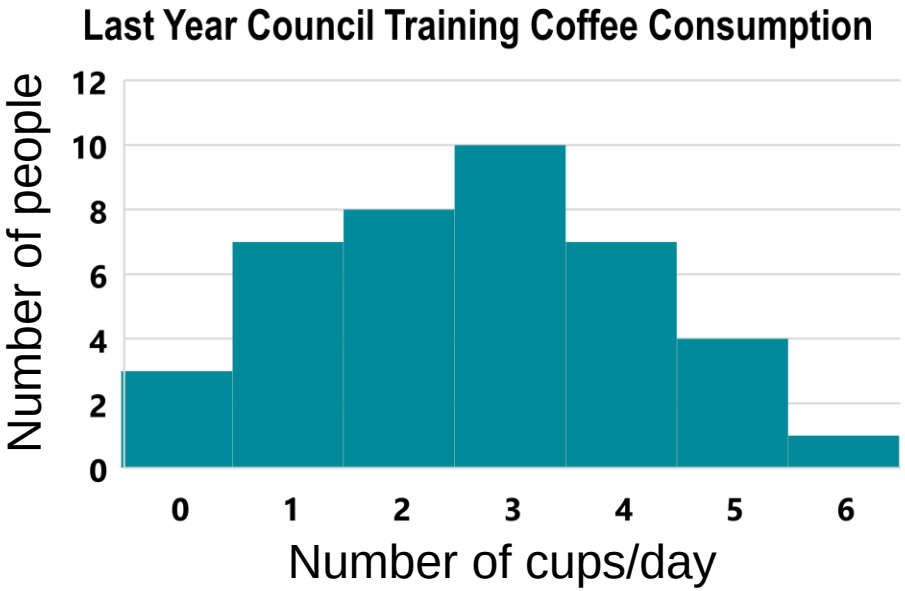

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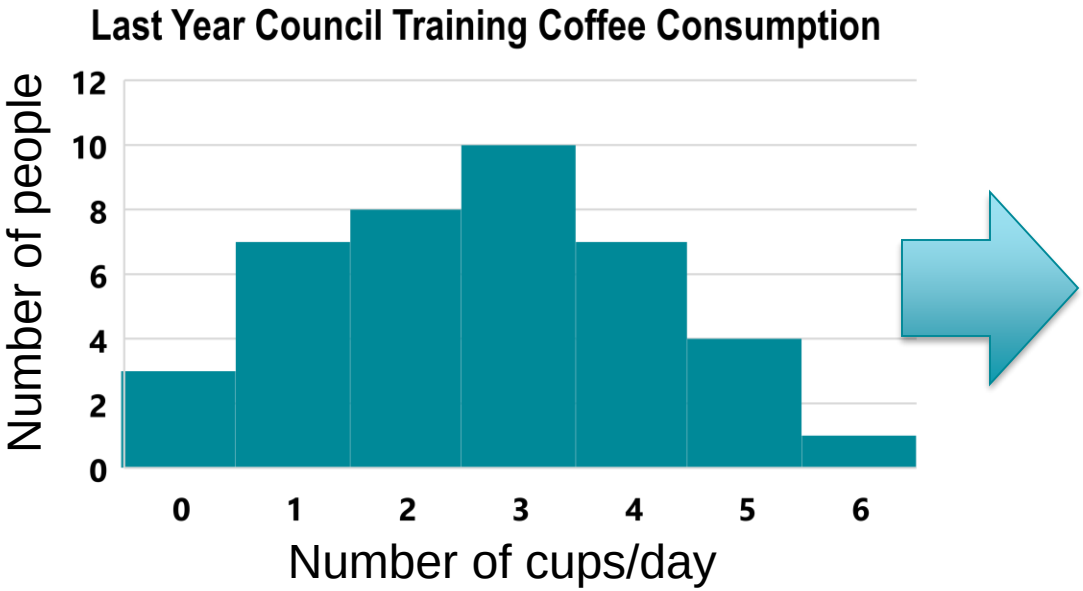

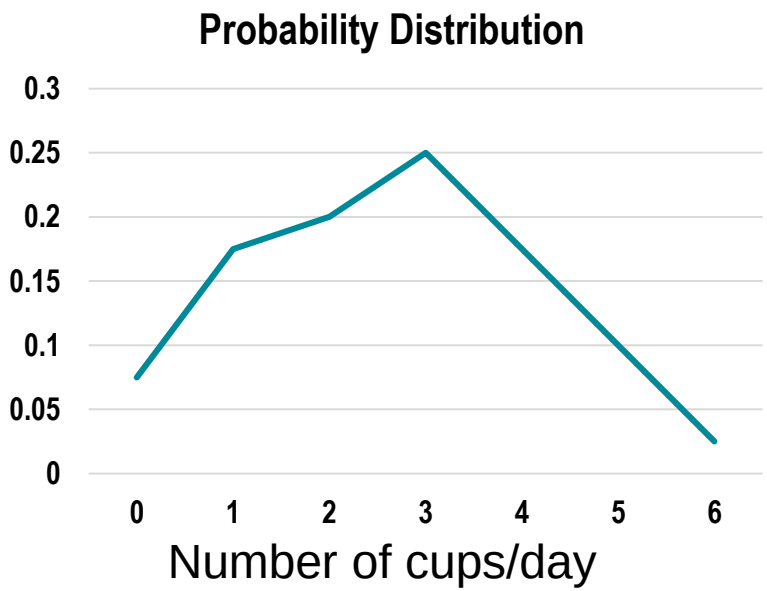

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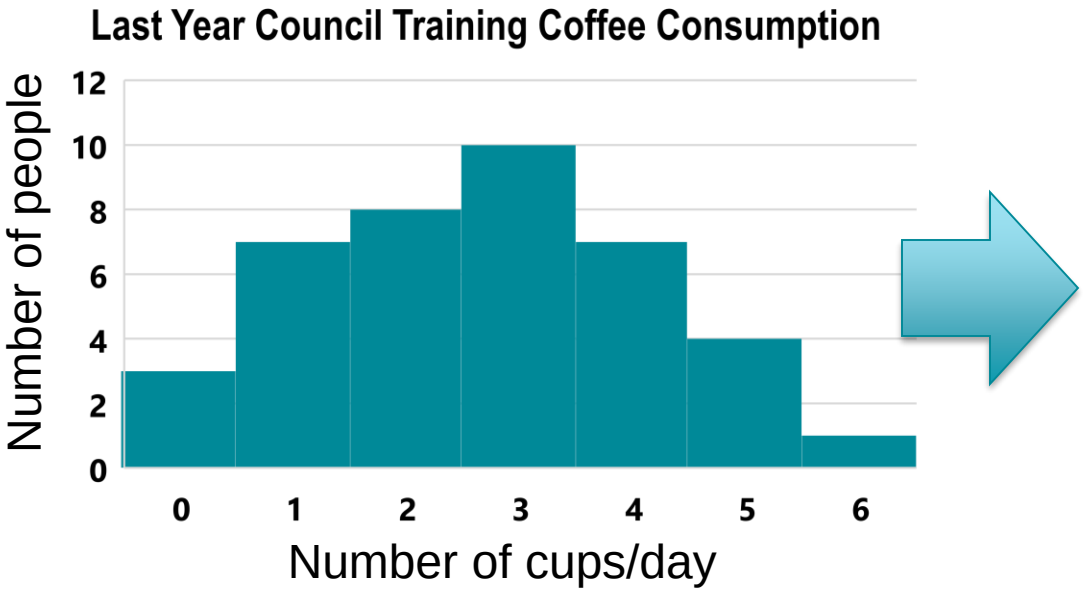

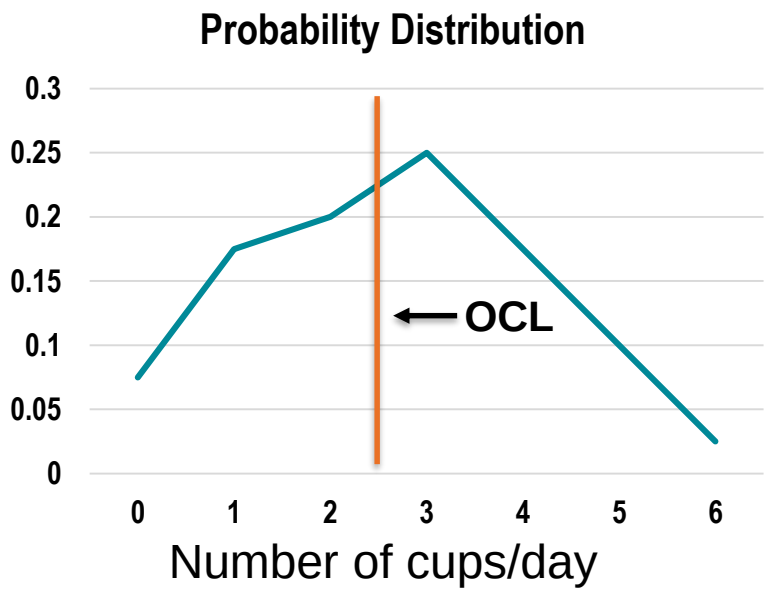

- 50% chance above/below 2.8 (OCL – over coffee limit)

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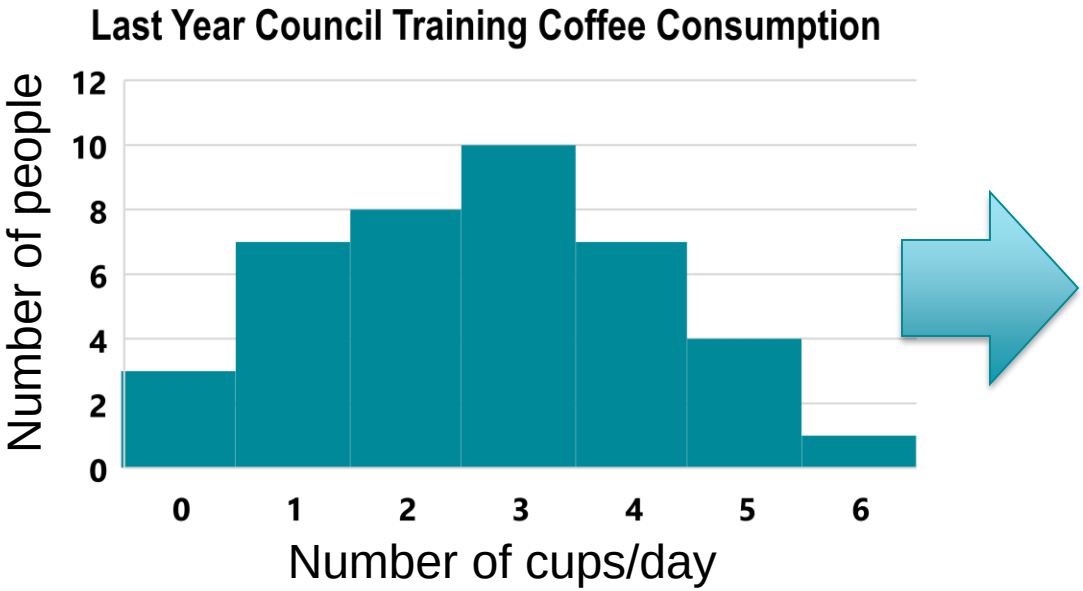
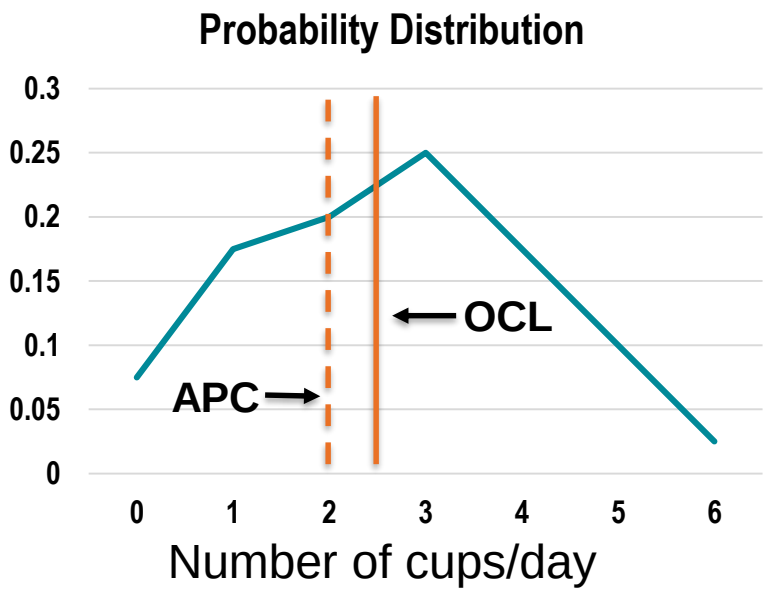




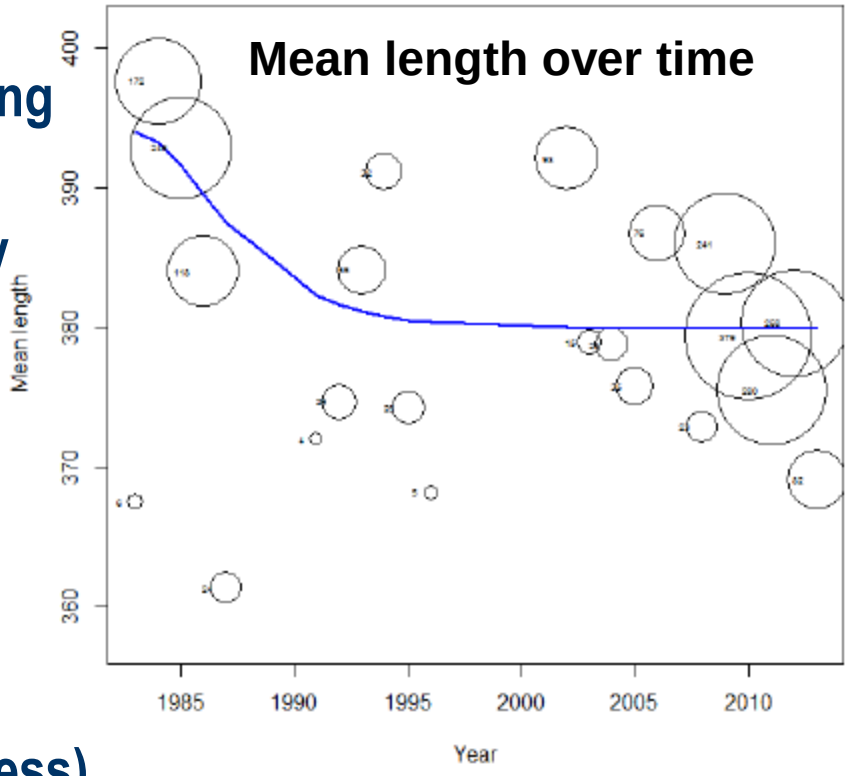
- 50% chance above/below 2.8 (OCL – over coffee limit)
- Consumption at Council Training may be higher than avg.
- Reduce risk: 45% chance below 2 (APC – acceptable purchase of coffee)

Stock Assessment Process

Developing & Communicating Recommendations

Uncertainty and the data poor situation

- MSY or proxies cannot be calculated
  - Catch level that constitutes overfishing is unknown
- Statistical uncertainty may be relatively low with data-poor methods
- However, should decrease with more information
  - Need to account for unmeasured (*likely*) uncertainty
  - Size of buffer can be “borrowed” from similar species (should not be less)



When assessments cannot calculate uncertainty, SSCs should set ABC:

- ❑ At the overfishing limit, OFL
- ❑ Below the OFL using uncertainty proxy from other stocks
- ❑ Refuse to set an ABC

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Summary

Assessments designed to answer mgmt. questions

Catch, abundance, & biology are key inputs

Variety of advanced technical methods tuned to diverse data availability scenarios

Assessments produce estimates of stock abundance, fishing mortality, and productivity

Stock forecasts provide technical basis to guide setting Annual Catch Limits

For More Information

NMFS stock assessment site

http://www.st.nmfs.noaa.gov/stock-assessment/index

FishWatch

http://www.nmfs.noaa.gov/fishwatch/

Status of Fisheries and FSSI Quarterly Reports

http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm

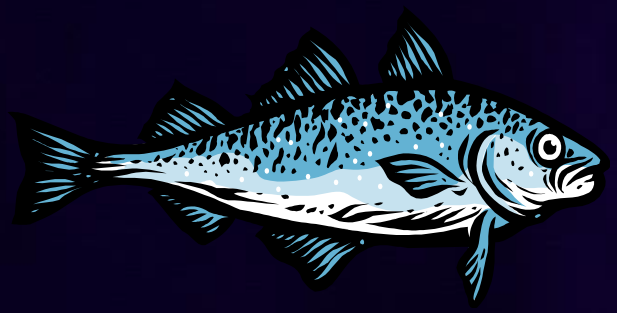
Species Information System for stock assessment and status determination data

https://www.st.nmfs.noaa.gov/sisPortal/sisPortalMain.jsp


Thank You
NOAA
R 445

BACK-UP SLIDES

Differences Between Fishery Catch Rates and Survey Trends for Yellow-eyed Cod

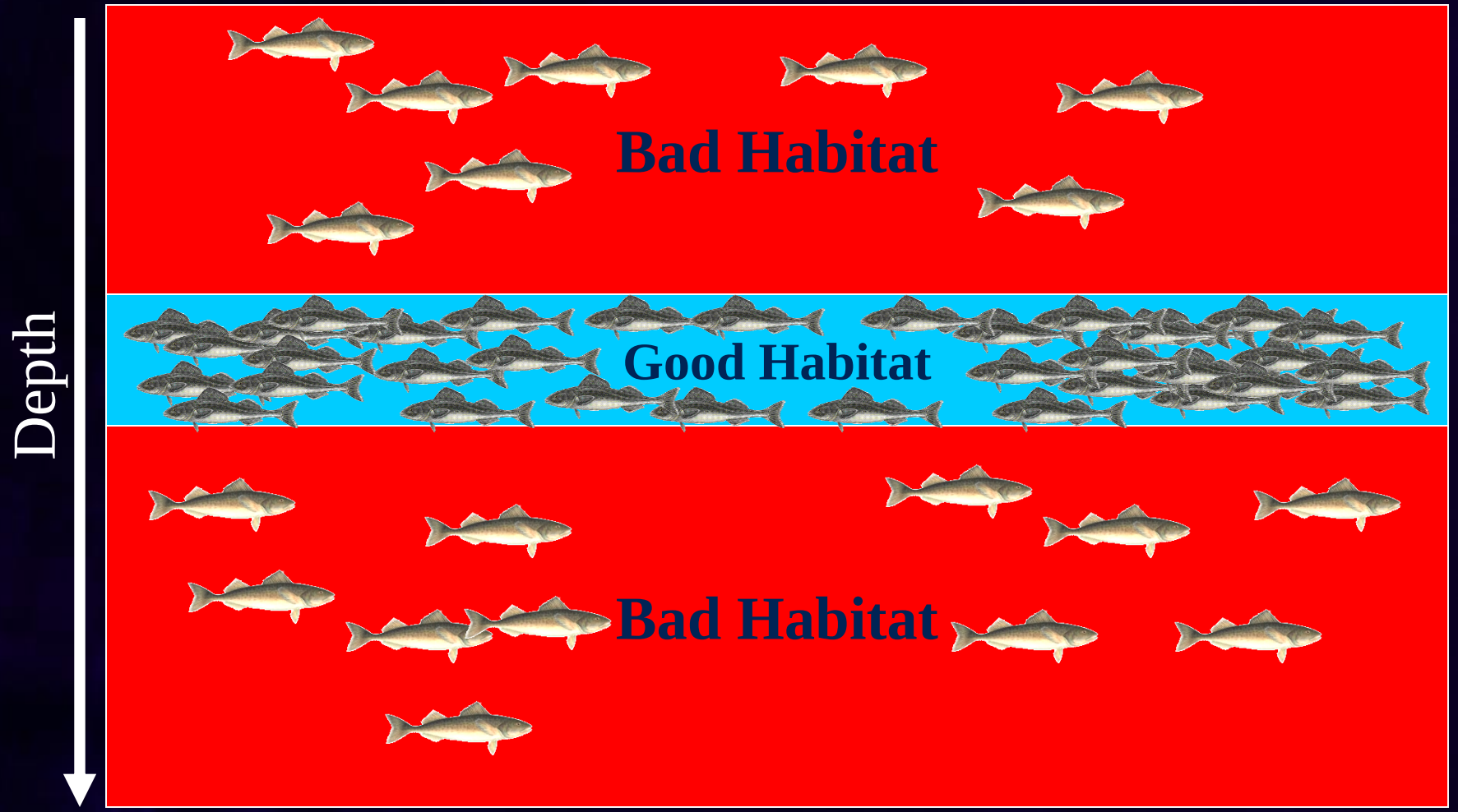


SSC Presentation

“Hyperstability”

- “If abundance is down, why are catch rates still good?”
- Fishery catch rates are a lagging indicator
- Surveys trends decline before catch rates
- Fishery catch rates are “hyperstable”

“Hyperstability”



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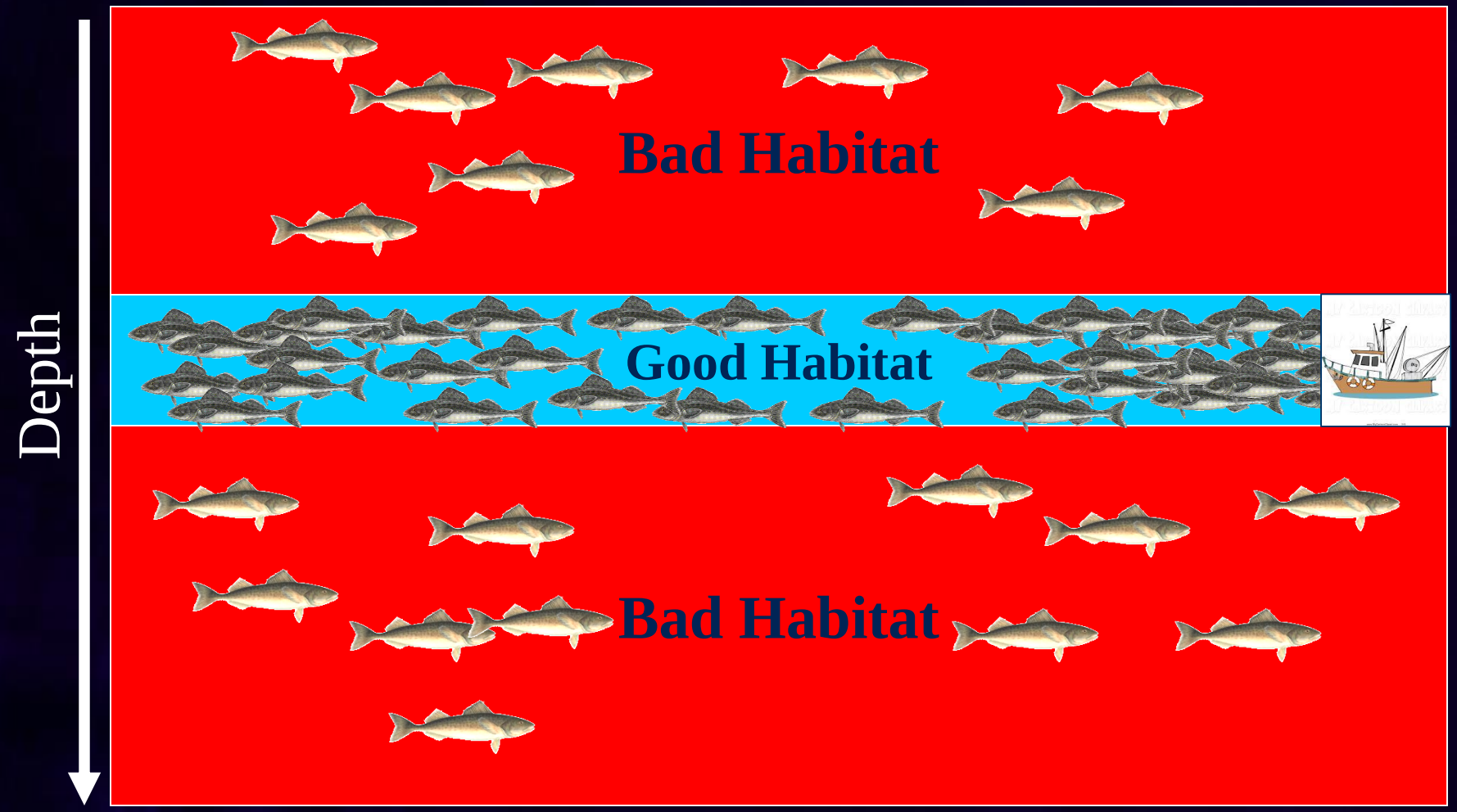

“Hyperstability”

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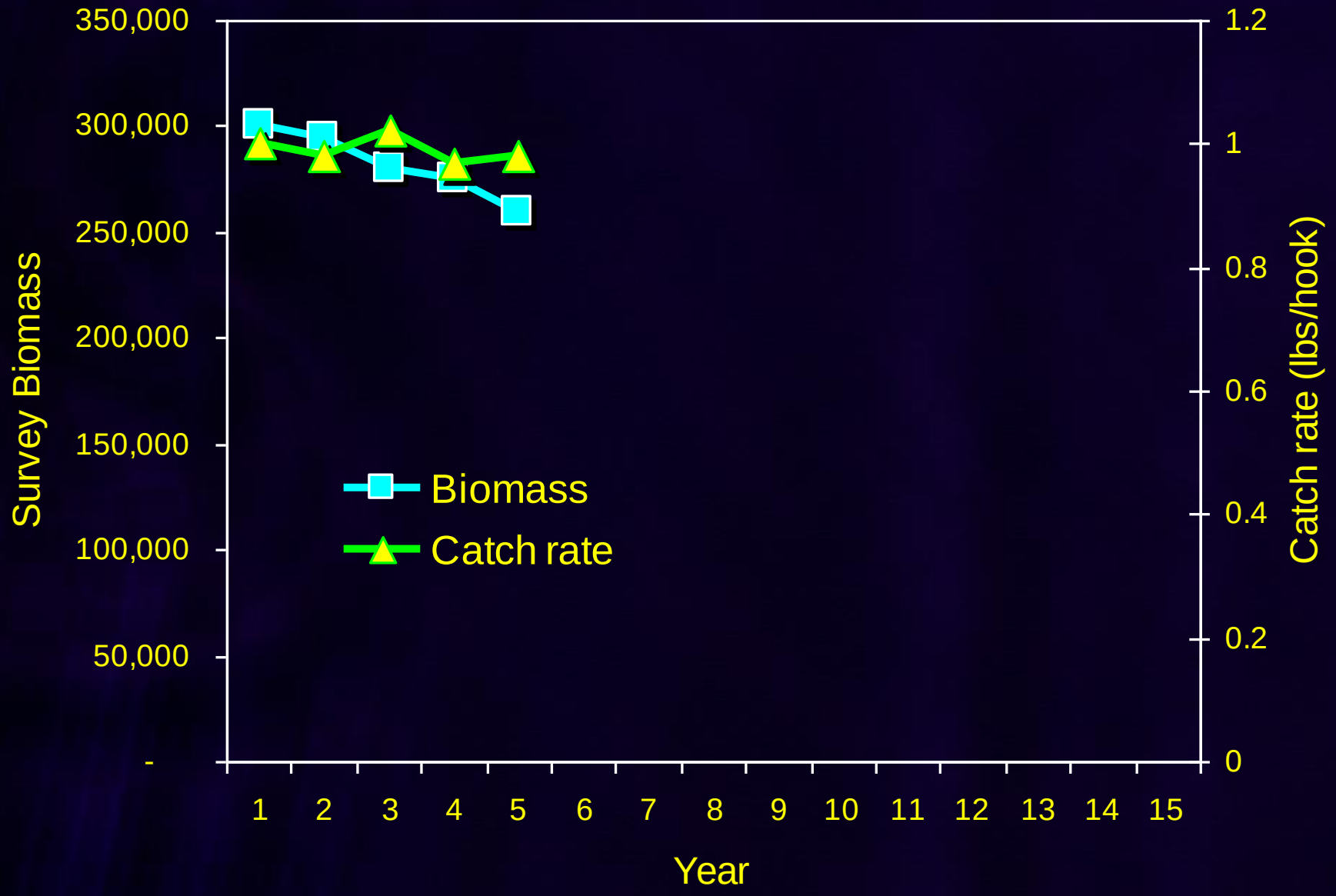

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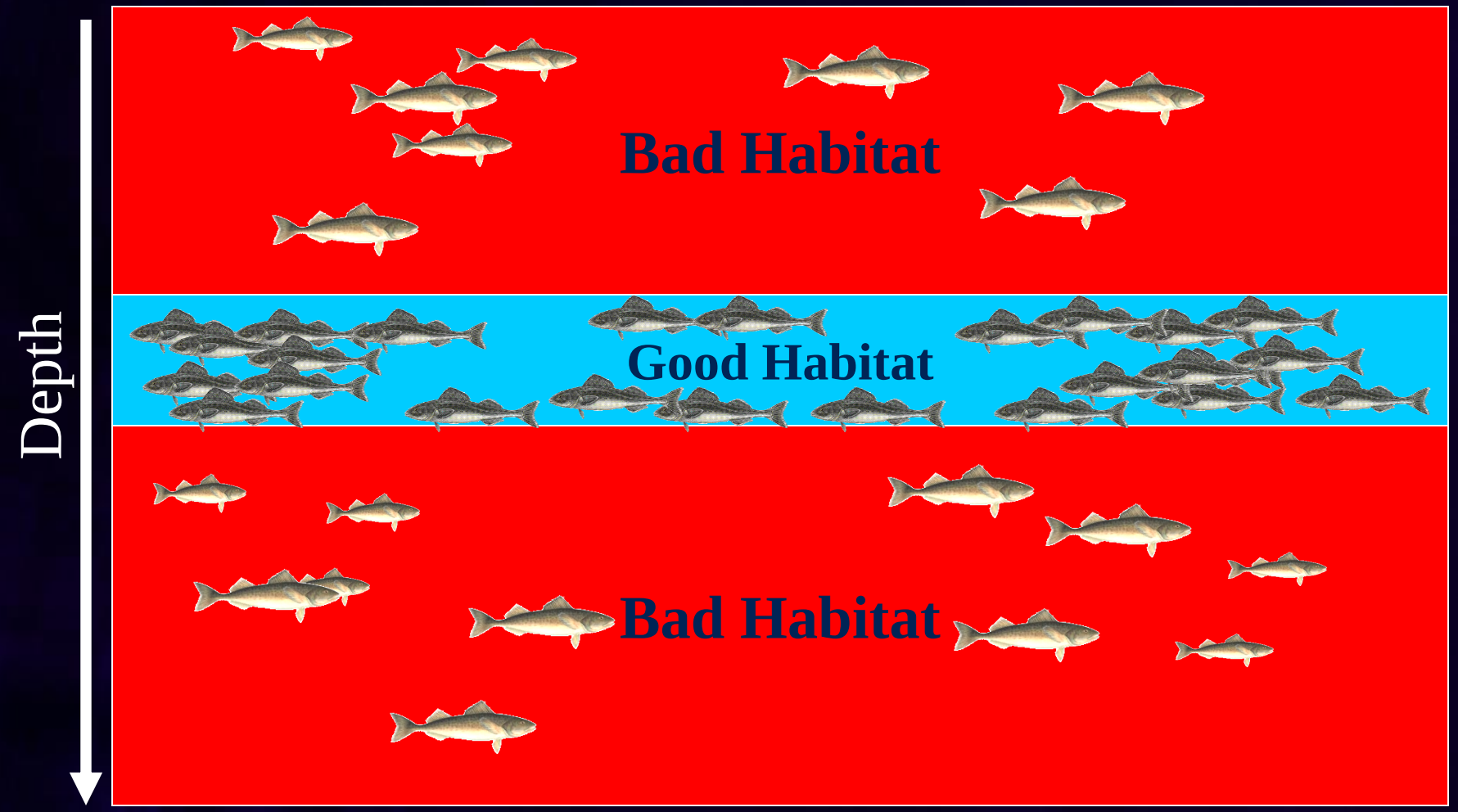

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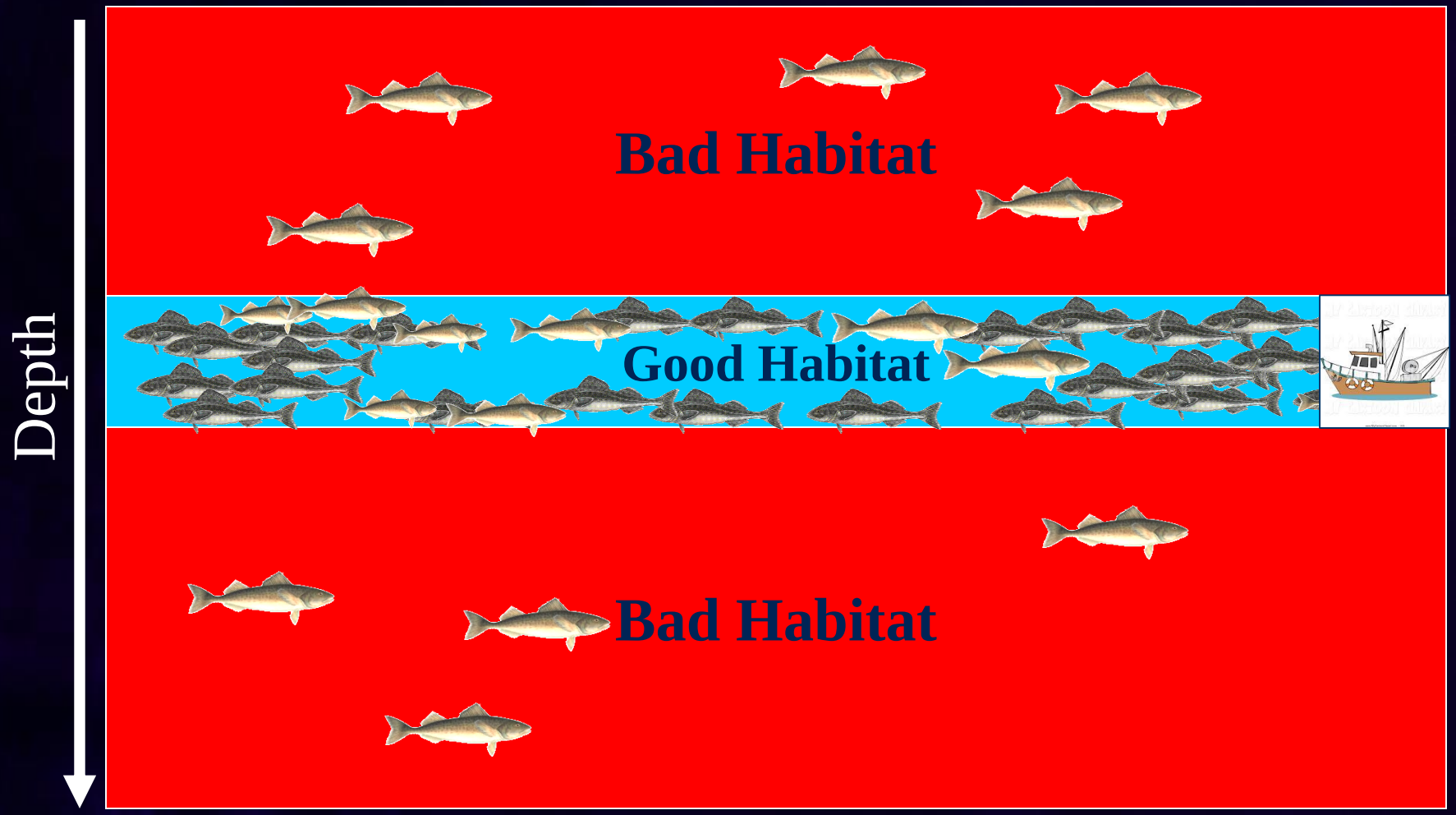

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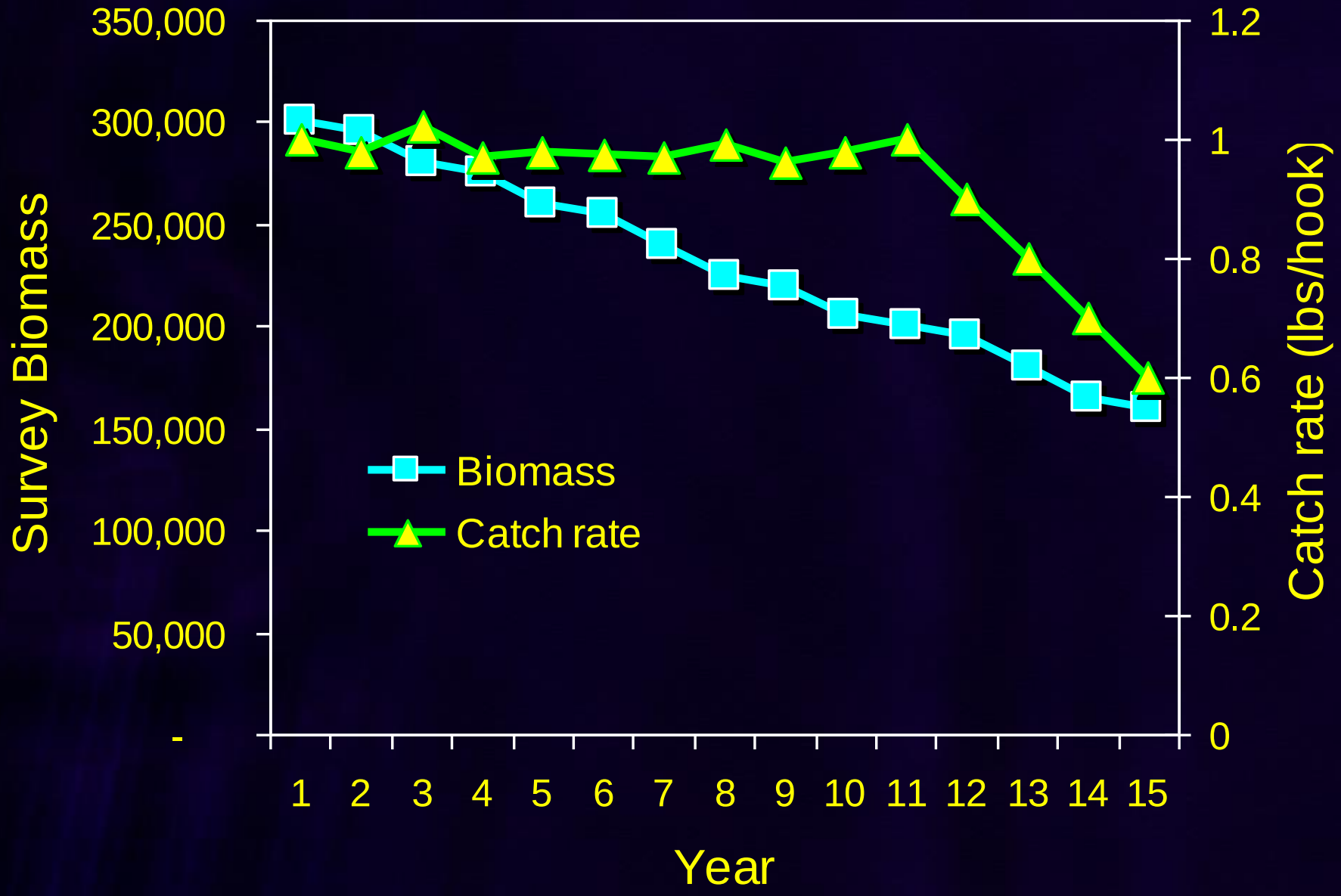


Assessment Jargon

- Stock; Population
  - Biological unit being analyzed, and its fishery
- Abundance; Biomass (B)
  - how many fish out there; total weight of the stock
- Reproductive potential; Spawning biomass (B, SB, SPB)
  - Produce 1000s of eggs per female, small fraction survive to be young fish
- Recruitment; Year-class; Cohort (R)
  - numbers of young fish entering stock each year
- Natural mortality (M)
  - Fraction dying each year due to natural causes
- Fishing mortality (F); Exploitation rate
  - fraction caught each year by the fishery increases overall mortality
- Annual Catch Limit (ACL) = (recommended F) times (Current Biomass)
- The maximum long-term average catch that the stock can produce is MSY

What does it mean to prevent overfishing?

- Intentional overfishing; i.e. setting a target that is beyond the best estimate of the overfishing limit. In principal, the US has ended this type of overfishing.
- Management shortcoming: this occurs when fishery management procedures fail to keep the catch below the overfishing limit. This could be accidental (procedures were in place but they didn't work), or structural (no credible accountability measures were in place to keep catch under control within the fishing season).
- Science uncertainty: this leads to retrospective revision of calculated historical abundance and fishing mortality such that the revised historical level now appears to have exceeded the limit, even though the catch was not over the ACL. This may happen every few years as major updates of assessments occur.
- Ecosystem overfishing: this occurs when the model/paradigm under which the tactical estimates of overfishing limits are calculated is wrong/biased/inadequate. We may not find out about this until decades later.

How is overfishing measured?

Catch compared to OFL

- Can be done each year, no new assessment needed
- High transparency for public, consistent with the ACL paradigm
- Forecast of ACL and OFL from past assessment does not account for recent recruitments, so need frequent assessment updates to keep ACL and OFL current
- Overfishing determination is only sensitive to management uncertainty
- Subsequent estimation of F by assessments does not result in overfishing determination

F compared to Flimit

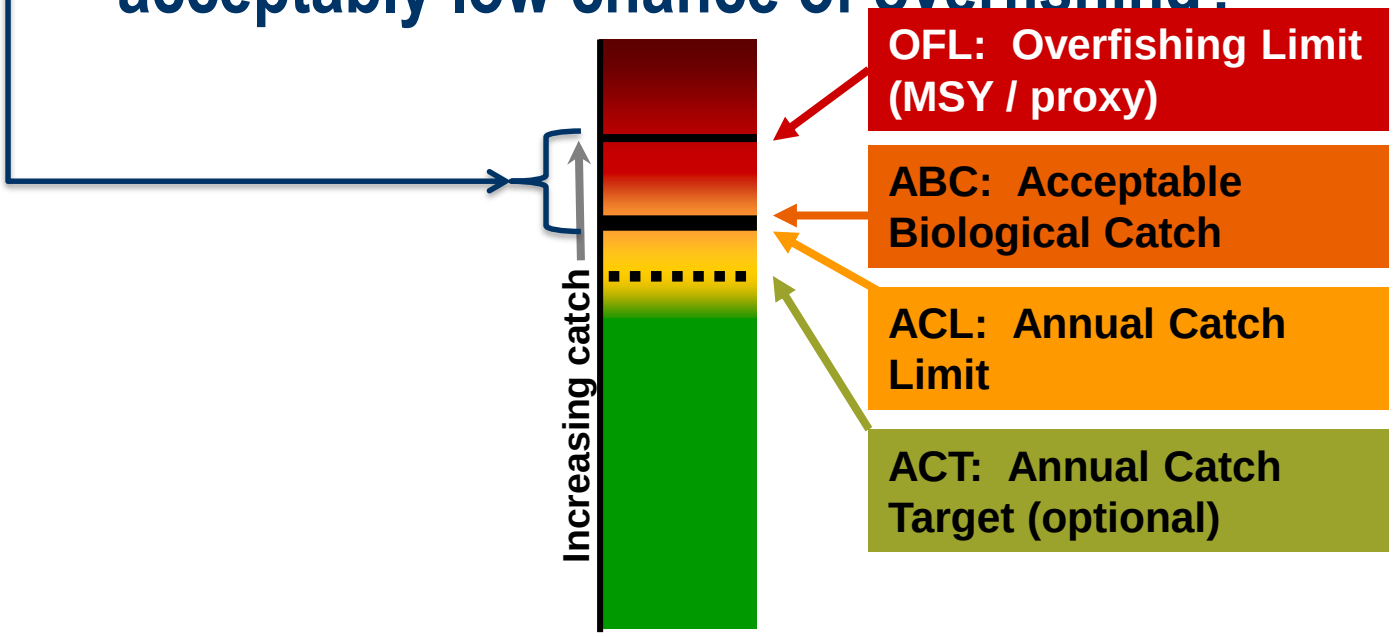
- Requires assessment to calculate current F and update Flimit
- Low transparency for public, keeping catch < ACL does not mean that new estimate of F will be < Flimit
- Because this is a hindcast, it is not sensitive to recent recruitments, but associated ACLs are sensitive
- Overfishing determination could be caused by management uncertainty or scientific uncertainty

Stock Assessment Process

Developing & Communicating Recommendations

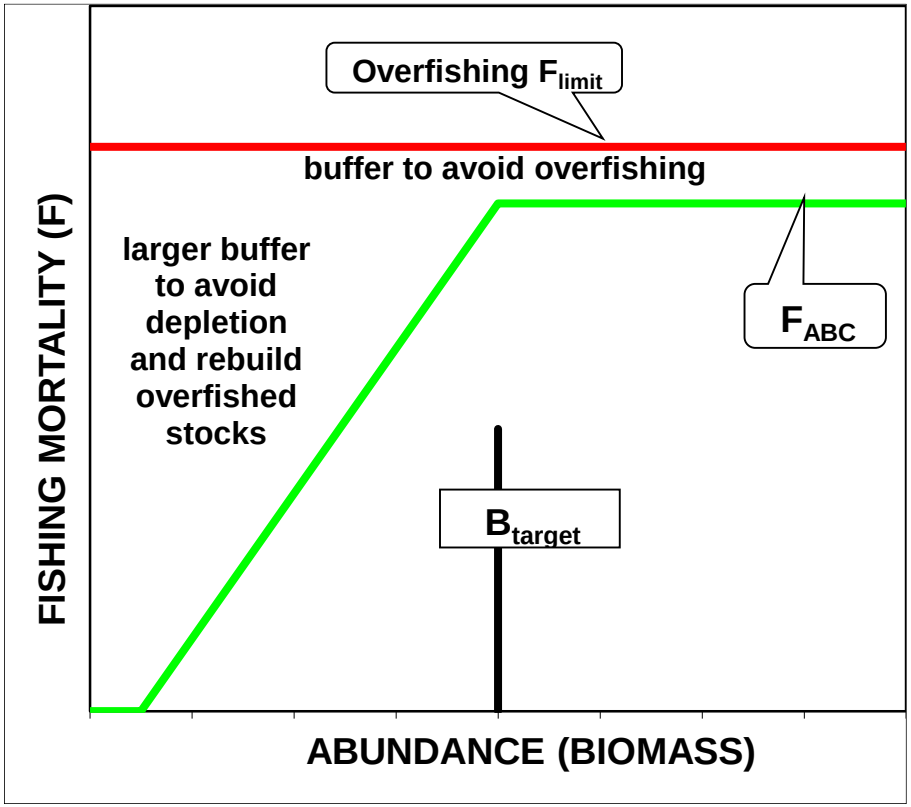
Proactive short-term advice: uncertainty

- Trade-off: How much catch is foregone to achieve an acceptably low chance of overfishing?



Harvest Control Rules

F is the fraction caught



Annual Catch = F times B